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SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

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BY

A. STRAHAN, Sc.D., LL.D., F.R.S.; J. S. FLETT, D.Sc., LL.D., F.R.S.; AND C. H. DINHAM, B.A.

WITH CONTRIBUTIONS BY

THE LATE C. T. CLOUGH, M.A., LL.D.; T. EASTWOOD, A.R.C.S.; AND A. F. HALLIMOND, B.A.

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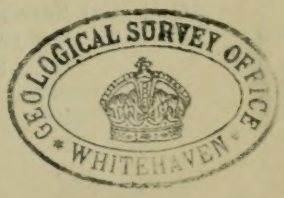

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PREFACE TO FIRST EDITION.

The fifth volume of the Special Reports on the Mineral Resources of Great Britain includes the description of some minerals, the utilisation of which is still the subject of experiment, or the working of which has ceased for various reasons. Salts of potassium are being sought, and the question whether they can be extracted profitably as a bye-product in the manufacture of cements and other materials from potash-felspars is receiving attention. Our home resources of phosphate of lime have been neglected for upwards of 20 years, not because they are exhausted, but through the competition of imported phosphatic materials. The shales from which alum is manufactured in this country are practically inexhaustible. The home supply of plumbago, on the other hand, is limited. The Cumberland plumbago had at one time no little reputation, and the mineral has been worked in Scotland, but none is now being raised in Great Britain. Molybdenite is recorded rather in the form of Museum-specimens than as a commercial product. The occurrence of chromite in limited quantities in Scotland has long been known, but the mines are now closed. Veins of talc and steatite are not uncommon in the serpentine of Cornwall, and in the metamorphic rocks of the Highlands of Scotland. Diatomite occurs in trifling quantities only in some lakes and rock-basins in England and Wales, and in rather greater abundance in Scotland, but in all cases the deposits are limited to an area of a few acres.

The chapters dealing with potash-felspar have been written by Mr. Dinham, and those on phosphate of lime by myself. In the remaining chapters Dr. Flett supplies all descriptions relating to Scotland, except some notes on molybdenite by Mr. Hallimond, and on graphite by Mr. Clough. The account of the Cumberland graphite is founded on notes by Mr. Eastwood.

A. STRAHAN,
Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.,
3rd March, 1916.

PREFACE TO SECOND EDITION.

The exhaustion of the first edition of this volume has provided an opportunity of inserting some additional information on potash-felspars, steatite and diatomite. The experiments on the making of cement from pegmatite-veins and the extraction of potash as a by-product have not led to commercial development, but increasing attention is being paid to the utilisation in bulk of such a rock as that of the Cornish dyke at Tresayes Downs for the making of glass.

A. STRAHAN,
Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.,
20th February, 1917.

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CHAPTER I.—POTASH-FELSPAR.

INTRODUCTION.

The actual and potential sources of potash[1] may be classified into:—

(*a.*) Inorganic.—Potash-bearing rock-minerals and deposits from saline waters.

(*b.*) Organic.—Plants, animals and organic refuse.

This report deals with certain potash-bearing minerals which occur more or less abundantly in Great Britain, but which, up to the present, have not been successfully utilised as a source of potash, although imported material has been extensively used in the manufacture of pottery and in other industries.

Most of the world's supply of potash is obtained from natural deposits which were formed by the evaporation of saline water. Of such deposits those of Stassfurt, in Prussia, may be considered typical, but they find no counterpart in Britain.

The most important mineral from the present point of view is potash-felspar. Potash-mica, leucite and the secondary minerals, alunite (alumstone), and glauconite have not yet proved practicable as direct sources of potash.[2] Alunite, however, is burnt in Hungary for the production of potash-alum and glauconite is used as a fertiliser, partly because of its potash-content.

There are two chief varieties of potash-felspar, known respectively as orthoclase and microcline. They are theoretically identical in chemical composition, being potassium-aluminium-silicate, with 16·9 per cent. of potassium oxide (K_2O), but they belong to different crystalline systems. They seldom occur in an absolutely pure state, for soda and other bases usually replace a portion of the potash. The percentage of potash, therefore, rarely reaches its full theoretical value.

These bases were generally present in the potash-felspar at the time of its crystallisation and are accounted for by:—

(*a.*) The solution in the potash-felspar of varying amounts of plagioclase soda-lime felspars (*e.g.*, albite and oligoclase).

(*b.*) The intimate intergrowth of potash-felspar with plagioclase felspar of this character.

(*a.*) Potash-felspar may dissolve as much as 28 per cent. of albite, giving rise to a felspar with as little as 12·2 per cent. of K_2O. Similarly albite, *i.e.*, soda-felspar, can dissolve as much as 12 per cent. of potash-felspar, giving rise to a felspar with a potash-content of 2·03 per cent.

---

[1] For a summary of the potential sources *see* C. G. Cresswell, *Journ. Soc. Chem. Ind.* (1915), pp. 387–393.

[2] For potash from leucite-bearing rocks and alunite, *see* Roger C. Wells, *U.S. Geol. Surv. Prof. Papers* 98—D (1916), pp. 37–40; W. H. Waggaman, *U.S. Dept. Agr. Bureau Soils, Circ.* 70 (1912); Skinner and Jackson, *ibid., Circ.* 76 (1913).

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(*b.*) The intergrowth of potash- and soda-felspar, known as 'perthitic,' is usually of so intimate a character that a mechanical separation of the two minerals is a practical impossibility. The two minerals may be intergrown in almost all proportions, but the typical perthite has a potash-content of about 7 per cent.

The name *pegmatite* is now used by geologists to denote an intrusive igneous rock, usually occurring as veins and dykes, in which the crystals of the component minerals are of large size compared to that which obtains in normal igneous rocks such as granite. The nature of the minerals depends upon that of the igneous masses with which the pegmatites are associated, and the same minerals tend to occur in both, though the pegmatites may often also contain minerals rare in, or absent from, the associated mass. Thus the pegmatites of Sutherland, associated with granitic gneisses, are granite pegmatites, and consist chiefly of quartz and felspar; other minerals such as white mica and minerals rich in magnesia and iron (*e.g.*, black mica, hornblende, etc.) are not abundant.

It should be noted that some writers on ceramics also include under the name pegmatite, rocks such as china-stone. Like the true pegmatites, these differ from felspar in containing a higher average percentage of silica, but, unlike them, are not necessarily rocks of coarse texture, being often derived from a granite of normal grain. The felspars in such 'pegmatites' have lost a certain proportion of their alkali content by processes of kaolinization.

In the type of pegmatite known as 'graphic granite' the quartz and felspar are regularly intergrown, instead of forming quite separate crystals; and the bulk of the pegmatite of Sutherlandshire consists of this material. The quartz and potash-felspar in graphic granite are present in more or less definite proportions, the average being quartz 27·5 per cent. and felspar 72·5 per cent.

EXTRACTION OF POTASH FROM FELSPAR.

The commercial success of any process for extracting potash from felspar depends upon the utilisation of the residue, which amounts to at least nine-tenths of the material treated. The residues may be used for cement, fertilisers and pottery-bases, and can be obtained in forms suitable for these purposes. Numerous methods have been devised for rendering the potash in felspar soluble, and among them the following may be mentioned:—

Natural agencies, and imitations of them. These have so far proved unsuccessful. Simple wet grinding extracts only 0·3 to 0·4 per cent. of the total alkali present. By fourteen grindings, assisted by electrolysis, about one-third of the total alkali present has been recovered.[1]

Treatment with chemical solutions. The treatment may be by either caustic alkalies (Eng. Pat. 13875, Fr. Pat. 351338, U.S. Pats. 862676 and 910662) or acids. Among the acids used are hydrofluosilicic acid followed by sulphuric (U.S. Pat. 772612 and

[1] Grünwald, 'The Raw Materials of the Enamel Industry' (1914), p. 8.

772657) or dilute hydrofluoric acid as an electrolysing agent (U.S. Pat. 851992, Cushman, April, 1907), which produce caustic potash.[1] Hydrofluoric acid acts catalytically in the presence of sulphuric acid solution, above 100° C., and the alumina and potash may be recovered as sulphate in this way.[2] Neutral salts are also used, such as calcium nitrate under pressure, which produces nitrate of potash.

Volatilisation of potash-salts. By heating felspar with gypsum and carbon, potassium sulphate may be volatilised (U.S. Pat. 789074). Several processes aim at recovering the potash from the flue dust produced when burning Portland cement (U.S. Pats. 912266, 1011172).[3] Among these is Junger's method (Eng. Pat. 26497 and 28970), in which it is claimed that less than 0·5 per cent. of the total potash in the felspar remains in the residual clinker.[4] One at least of these processes is working in California.

Potassium chloride is collected after volatilisation in a method of Herstein, where felspar is fused with calcium chloride and a carbonate.[5]

Dry processes for the separation of potash as hydroxide or carbonate. After roasting felspar with the carbonate, nitrate, or hydroxide of calcium (or sodium), and blowing steam through the product, potassium carbonate or hydroxide is produced (French Pat. 352275). Carbonate is also formed by the action of ammonium carbonate vapour under pressure on silicates, with or without previous burning with calcium or magnesium oxides or carbonates (U.S. Pat. 1058665, Gelléri, Apr., 1913). The residues are utilisable for Portland cement. In the Ward and Wynants process[6] the felspar is ground and fritted with lime and fluorspar, lixiviation giving hydroxide and silicate of potash, the latter being decomposed by carbon dioxide.

Dry processes for separation of potassium as chloride. In the Rodin process (U.S. Pat. 641406) felspar is fritted with lime and salt. In the Bassett invention (U.S. Pat. 1072686, Sep., 1913) salt only is used; the sodium and potassium chlorides are leached out and separated by crystallisation, leaving as residue a white mass which is suitable for pottery-enamel or paper-filling.[7] The Herstein process mentioned above can be modified so as to produce potassium chloride in solution, the residue being available, without regrinding, for Portland cement.[8] Extensive experimental trials have been made upon the Cushman-Coggeshall processes

---

[1] *Min. Res. of United States* (1911), ii, p. 898.

[2] Foote and Scholes, *Journ. Ind. and Eng. Chem.*, iv, 5 (May, 1912), p. 377 Compare the Spiller process (*see* Thorpe, *Dict. App. Chem.*, vol. iv, p. 357).

[3] See also Wright, *8th Internat. Cong. App. Chem.* xv, 1912, pp. 117–124.

[4] See *Journ. Soc. Chem. Ind.* (1913), pp. 486, 524; (1915), p. 421. Other patents: Huber and Reath, *ibid.* (1916), p. 966, and Spackman and Chester, *ibid.* (1916), p. 1221.

[5] Thorpe, *Dict. App. Chem.*, vol. iv, p. 357; Herstein, *Journ. Ind. and Eng. Chem.*, iii, 6 (June, 1911). See also Brown's patent, *Journ. Soc. Chem. Ind.* (1915), p. 229.

[6] See *Chemical News*, cx (1914), p. 175.

[7] See *Min. Res. of United States* (1913), ii, p. 100, and *Journ. Soc. Chem. Ind.* (1913), p. 977.

[8] Herstein, *loc. cit.*, and *Min. Res. of United States* (1911), ii, p. 899.

(U.S. Pats. 987436, 987554, March, 1911).[1] In these patents felspar is treated with lime, rock-salt, and calcium chloride, and passed into a rotary kiln. The product contains 7·12 per cent. of potassium chloride, and 12·25 per cent. of free lime, and is used as a fertiliser.

A method has recently been described for producing potassium chloride, along with soda-ash, phosphoric oxide and alumina, by first decomposing phosphate-rock by heating with common salt and carbon dioxide, and then decomposing felspar by heating in contact with the phosphorus and carbon oxychlorides thus formed.[2]

Dry processes for producing potash as sulphate. By the Thompson process (U.S. Pat. 995105, June, 1911) felspar is fused with sodium bisulphate and salt, and sodium and potassium sulphates are extracted on leaching with water.[3] The Hart method[4] (U.S. Pat. 1062278, May, 1913) aims at producing aluminium sulphate and silica as well as potassium sulphate. The felspar is fused with carbon and potassium sulphate to a glass, and the product, leached with sulphuric acid, yields potash-alum. An alkali sulphate is also produced in the Hambloch and Gelléri patent.[5]

Other methods include the following:—

Potash is produced as alum, together with orthophosphoric acid and dicalcium silicate, in the Cowles process,[6] the felspar being mixed with rock phosphate, and the product leached with sulphuric acid. If hydrochloric acid be used instead, potassium-aluminium chloride is produced. The patent of Morse and Sargent (U.S. Pat. 1041327, Oct. 1912) is intended to recover potassium as chloride and sulphate mixed, together with sulphur oxides, and to yield a residue for Portland cement.[7] In Peacock's process (U.S. Pat. 1035812, Aug. 1912) felspar is heated with limestone and the potash obtained as silicate (water-glass) along with pure alumina.[8] By a new Swedish process felspar is used to obtain a glassy slag in the electric production of ferro-silicon. The potash in the slag is more soluble than in felspar, and the ground slag is used as a fertiliser.[9] A patent of Ross[10] aims at fixation of atmospheric nitrogen simultaneously with the volatilisation of potash. Among other patents claiming to produce

[1] See *Min. Res. of United States* (1912), ii, p. 900; (1914), ii, p. 25; also Cushman and Coggeshall *8th Internat. Cong. App. Chem.*, v, (1912), pp. 33–49; *Journ. Ind. and Eng. Chem.*, iv, 11 (Nov., 1912), pp. 821–827; *ibid.*, vii, 2 (Feb., 1915), pp. 145–151; *Metall. and Chem. Engin.* (1912), p. 728; *American Fertilizer* (Dec. 12, 1914), p. 21; *Am. Inst. Min. Eng.*, Dec. 2, 1914; *Journ. Soc. Chem. Ind.* (1915), p. 79.

[2] *Chemical Engineer*, xxi, No. 5, and *Chemical News*, cxii (1915), p. 266.

[3] See *Min. Res. of United States* (1911), ii, p. 899, or (1913), ii, p. 101.

[4] *Min. Res. of United States* (1912), ii, p. 901; *ibid.* (1913), ii, p. 99; and Hart, *8th Internat. Cong. App. Chem.* ii (1912), pp. 117–118; *Journ. Ind. and Eng. Chem.* iv, 11 (Nov., 1912), pp. 827, 828.

[5] *Journ. Soc. Chem. Ind.* (1912), p. 686; (1913), p. 602.

[6] *Journ. Ind. and Eng. Chem.* (Apr., 1913), pp. 331–335.

[7] See *Min. Res. of United States* (1913), ii, p. 98.

[8] See *Min. Res. of United States* (1912), ii, p. 902.

[9] 'The World's Supply of Potash,' Imperial Institute (1915), p. 44.

[10] *Journ. Ind. Eng. Chem.* (1913), pp 725–729.

soluble alkali from felspar are those of Neil (U.S. Pat. 1034281),[1] Lindblad (Eng. Pat. 23898),[2] Melkman (U.S. Pat. 1148850), Fraser Holland and Miller (U.S. Pat. 1196734),[3] Quinney,[4] Peacock (U.S. Pat. 1202215),[5] Hart,[6] Brown,[7] etc.

The following processes are more particularly directed to obtaining potash and fertilisers:—Drury (Eng. Pat. 15432),[8] André,[9] Peacock (U.S. Pat. 1124798) and Bassett (U.S. Pats. 1172420 and 1194464).[10]. Further references to these and other processes are readily found in the annual indices to the Journal of the Society of Chemical Industry, under the heading 'Felspar.'

Comparative studies of the various processes have been made by Cushman and Coggeshall[11] and by W. H. Ross.[12]

Experiments have recently been made on the production of cement from felspar and the extraction of potash as a by-product; felspars from Sutherland, Cornwall and Sweden were used. The results of the experiments have been published in the "Journal of the Board of Agriculture," vol. xxiii, 1917, pp. 1087-91.

Uses of Potash-Felspar.

As regards other uses of potash-felspar, or of the residues left after the extraction of the potash, experiments, now being made by the Department of Agriculture of the United States on their value as fertilisers, show that finely ground felspar is of use for certain crops.[13] The most important consumers, however, are the manufacturers of pottery, enamel ware and electric ware.

The felspar forms part of the body in the finest wares, but is chiefly used as a glaze, owing to its reluctance to crystallise. For this purpose potash-spar is rather better than soda-spar, and both are much superior to the lime-felspars. The finest pottery demands a spar with less than 5 per cent. of quartz, but good results can be obtained with 15 or 20 per cent., or even more. Other uses for the lower grade felspars are: for cementing the abrasive grains in emery- and corundum-wheels, as a coating for tarred surfaces in the manufacture of roofing material, for surfacing concrete, in coal-washers, and as a poultry grit.

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[1] *Journ. Soc. Chem. Ind.* (1912), p. 816.
[2] *Ibid.* (1913), p. 364.
[3] *Ibid.* (1915), p. 1059.
[4] *Chem. News* (1915), 112, pp. 189–191.
[5] *Journ. Soc. Chem. Ind.* (1916), p. 1217.
[6] *Journ. Ind. Eng. Chem.* (1915), p. 670.
[7] *Journ. Soc. Chem. Ind.* (1915), p. 229.
[8] *Journ. Soc. Chem. Ind.* (1915) p. 973; (1916) p. 1075.
[9] *Comptes Rendues* (1913), p. 157, p. 856; (1916) pp. 133-136, 162.
[10] *Journ. Soc. Chem. Ind.* (1916), pp. 468, 1016.
[11] *8th Internat. Cong. App. Chem.* v (1912), pp. 33–49.
[12] *Ibid.*, pp. 217–229, and *Bureau Soils, U.S. Dept. Agr. Circ.* 71 (July, 1912).
[13] A. S. Cushman, 'The Use of Felspathic Rocks as Fertilisers.' Bull. No. 104 Bureau of Plant Industry, U.S. Dept. of Agriculture, 1907.

CHAPTER II.—POTASH-FELSPAR CONTINUED.

SOME PEGMATITE-VEINS IN SCOTLAND.

Between Lochs Laxford and Inchard (Fig. 1).

The Lewisian gneiss of this district is everywhere traversed by pegmatite-veins, generally of a pink colour.

The veins range generally in a W.N.W. direction along the banding of the gneiss and have usually the steep dip which is observable in that banding. They are all more or less irregular. Their average thickness varies from 3 or 4 feet to as many yards, but they may locally swell out to a width of 20 to 30 feet or more.[1]

Some of the broader veins, having a thickness of 30 yards or so for several hundred yards, have been the object of especial attention, and have been found to contain inclusions of gneiss to the extent of about one quarter or one third of their bulk. Such inclusions are not easily separable by the eye (nor, it is to be expected, mechanically) from the vein-matter. The steepness of dip and narrowness of the veins would limit the amount available by quarrying, but on some hill-sides where the dip of the vein and the slope of the ground approximately agree, the pegmatite forms 'cakes' which could easily be worked open-cast.

Of the veins shown on Fig. 1 the most promising lie near the north shore of Loch Laxford, east of the entrance to Loch a' Chathaidh, but they are in only one or two cases as much as 30 yards broad over more than a few yards in length, the average breadth being perhaps less than 12 feet. The quantities available without mining or pumping in the more promising and accessible veins have been roughly estimated as follows for the localities indicated on Fig. 1:—

Locality on Fig. 1.	Average breadth of vein. yds.	Probable minimum quantities of pegmatite in tons.
B ...	25	17,000
C ...	3	9,000
D ...	25–30	22,000
E ...	?	2,800
F ...	30	140,000

The raising of pegmatite at Locality F by open-cast work would involve the removal of about an equal quantity of country-rock. Probably not more than two-thirds of the vein is pegmatite.

The number of localities therefore in which there is any considerable quantity of pegmatite available by quarrying, above the level of the water, is strictly limited. Further work would necessitate the removal of large quantities of gneiss, or mining. On the other hand, the abundance of veins which are accessible to quarrying operations is a partial compensation, provided that temporary means of transport can be provided.

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[1] *Memoirs of the Geological Survey of Great Britain:* 'The Geological Structure of the N.W. Highlands of Scotland' (1907), p. 122.

FIG. 1.—MAP SHOWING THE DISTRIBUTION OF PEGMATITE-VEINS NEAR LAXFORD.

Transport would be attended with exceptional difficulties owing to the hilly character of the ground. The most accessible localities are D and F (Fig. 1), where the material could be hoisted directly into carts and run a short distance to the sea.

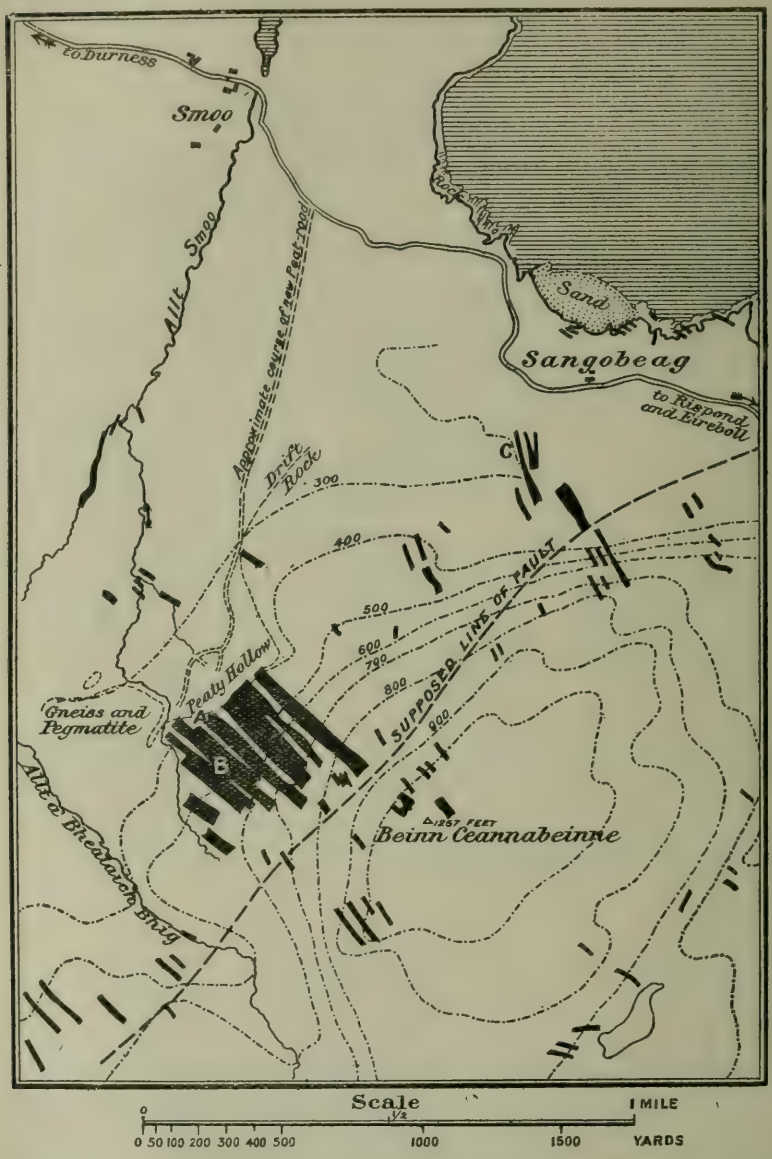
Water is abundant in the valley-bottoms, but few streams descend the hill-slopes near the pegmatites. There is little or no peat.

Between Durness and Eireboll (Fig. 2).

The banding of the gneiss in this district has a constant N.W. strike, and a dip which is seldom more than a few degrees inclined either way from the vertical. The veins of pegmatite are closely concordant with the banding in dip and strike.

The average thickness of the veins is perhaps rather greater than it is in the Laxford area; in the majority it may be less than 20 ft., but it not infrequently reaches 20 yards. Many of the veins appear to continue for a mile or more. Inclusions of gneiss are probably less frequent than at Laxford. Five or six veins of unusual breadth occur about 700 yards W.N.W. of the summit of Beinn Ceannabeinne (Fig. 2). At one place, A, near the end of the new peat-road, in a breadth of 100 yards of pegmatite, gneiss constituted not more than 10 per cent., and is distributed in two or three bands only. The pegmatite appears to be practically free of other inclusions.

Fig. 2.—Map showing the distribution of Pegmatite-veins between Durness and Eireboll.



Farther to the N.E. for about 300 yards along the lower slopes of the hill, nearly every exposure of rock consists of pegmatite. In this space bands of country-rock are few and range from a foot to a yard or two in width; they certainly do not total 10 per cent. of the whole mass.

This belt of veins is thus about a quarter of a mile broad; to the N.W. it disappears from view under the peat-hollow shown in Fig. 2, but to the S.E. it can be seen rising up the slopes

towards the top of Beinn Ceannabeinne, the veins, however, rapidly decreasing in number between the 700-ft. and 800-ft. contour-lines. Assuming its length to be 330 yards and its width to be ¼ mile, and deducting 10 per cent. of the mass for inclusions of country-rock, we get an estimate of six and a half million cubic yards, equivalent to more than 12,000,000 tons of pegmatite matter. This is the most important body of pegmatite at present known in Sutherland. Quarrying operations would be attended with no unusual difficulties. The cover is thin, and would include no solid rock in properly selected localities. The veins are broad and practically vertical, and could be followed downwards without developing a hanging wall. There are no overhanging crags to render the quarrying dangerous.

The nearest existing 'port' is a small harbour at Rispond, at the mouth of Loch Eireboll, not more than 3½ miles from the peaty hollow, but the nearest pier available for a larger cargo-boat is at Portnancon on Loch Eireboll, at a distance of about 7 miles by road.

Other veins occur near the village of Sangobeag (Fig. 2, p. 7), only ½ mile from the sea. One is 45 yards across at least without any visible inclusions of gneiss, but the full extent of the veins is masked by drift or scree. They are situated on a steep slope immediately above the village.

At Overscaig, Loch Shin.

At one place on the north shore of Loch Shin, about 620 yards S.E. from Overscaig Farm, and about ¾ mile S.E. of Overscaig hotel, a vein of pegmatite, more than 20 ft. thick, has been intruded among some basic igneous rocks. It is scarcely, if at all, foliated, and consists mostly of pale-pink felspar (microcline-perthite), with some quartz. The sides of the vein are irregular and not strictly concordant with the foliation planes of the basic rocks on either side, but the vein as a whole probably behaves like a sill. The dip of the lower side of the vein appears to be about 25° (1 in 2) and to vary in direction from E. by S. to N.E.

At the upper end of a small valley (250 yards S. 30° E. from Overscaig Farm, and about 400 yards W. 40° N. of the exposure just described, a minute burn falls over an exposure of pegmatite, similar to that described above. Only a few feet of rock are seen, and no estimate of the thickness is possible, nor can it be said for certain that it is part of the vein first mentioned.

One, or perhaps two, veins of pegmatite, 2-5 ft. thick, are visible a few yards to the S.E. of that first described, and a conspicuous knob stands close to the road N.W. of Shinness House about 7 miles away, but no other occurrences are known in the neighbourhood. The evidence is insufficient for an estimate of the quantity of pegmatite available.

The following analysis may be taken as fairly representing the composition of the first-mentioned vein where it is at present exposed to view:—

Pegmatite-vein on the shore of Loch Shin. (*One-inch Map*, 108. *Lab. No.* 434.)

SiO_2	72·94	MgO	·08
TiO_2	·06	K_2O	7·42
Al_2O_3	14·26	Na_2O	3·49
Fe_2O_3	·21	Li_2O	Trace.
FeO	·22	H_2O at 105° C.	·05
MnO	·11	H_2O above „	·17
(CoNi) O	nt.fd.	P_2O_5	·49
BaO	·25	FeS_2	nt.fd.
CaO	·23	CO_2	·06
		Total	100·04

E. G. Radley,
26*th November*, 1914.

Calculation from this analysis gives (percentages by weight)—

Microcline	43·96
Albite	29·61
Felspar	73·57
Minor constituents	2·38
Quartz, &c.	24·09 by difference.
	100·04

The dyke of Ben Chaipaval, Harris.

Maps: One-inch (Ordnance) Sheet 89; six-inch (Ordnance) Inverness-shire (Harris), 17 N.E., S.E. Latitude 57° 49′ 0″ N. Longitude 7° 6′ 0″ W.

This locality has not been mapped by the Geological Survey, but the following notes, taken from the late Professor Heddle's description,[1] are reproduced here on account of the considerable size of the vein.

"A number of [graphic] granite dykes are to be seen in the south end of Harris. Towards the south-west these run nearly parallel to one another" in a general N.N.E. and S.S.W. direction. "The dyke of Ben Chaipaval is markedly the largest of the series, and is the grandest granite dyke in Scotland. Nearly two miles long, of about 30 ft. in thickness, and protruding with a smooth and inaccessible front in some places to nearly an equal height above the surface, it forms quite a feature in the scenery." This vein contains microcline, quartz, and greenish potash mica. The microcline was found by Professor Heddle to contain 12·98 per cent. K_2O, and 1·89 per cent. Na_2O. The potash content of the whole rock is probably similar to that of the veins previously described. The dimensions given denote about 100,000 tons of pegmatite for each six feet of depth when the whole length of the vein is quarried; owing to the wall-like protrusion of the dyke, the working should be open-cast until at least a quarter million tons have been taken out.

Chaipaval (1201 ft. high) is on a peninsula, no part of which is more than a mile from the sea, and is three miles from the main road from Rodel and Obbe to Uig and Tarbert.

Other pegmatite dykes are recorded from the same neighbourhood, one 16 ft. wide on Stromay Island; another, on the coast of the mainland opposite, is 30 ft. wide, and the potash felspar

[1] M. F. Heddle. *Trans. Roy. Soc. Edin.*, xxviii (1876–7), p. 209.

from this vein showed 13·13 per cent. K_2O, 2·51 per cent. Na_2O. These localities are about three miles S.S.E. of Chaipaval, and half a mile from the main road.

The following notes are from material supplied by Mr. G. V. Wilson:—

Strontian District.

Maps: One-inch (Ordnance) 52; six-inch Argyllshire 17 S.E. and S.W., 18 S.E. and S.W.

Several tons of potash-felspar-pegmatite are lying loose on the spoil heap of the Fee Donald (abandoned) galena mine at the end of the road about 4 miles N.E. of Strontian. The pegmatite forms part of the country rock, and there is reason to believe that pegmatite may occur in considerable quantity in the neighbourhood.

About $3\frac{1}{2}$ miles N.N.W. of Strontian, near the old track beside the Allt Coire an t-Suidhe, and about 200 yards above the old top working of the lead vein at this locality, a fine pegmatite dyke is seen, consisting essentially of quartz and orthoclase, with included bands of mica-schist up to 6 ft. in width. The dyke is 50 ft. wide in places, and about a quarter of a mile long. Polloch, on Loch Shiel, is 2 miles down hill to the N.N.W.

On Ben Resipol, 2 miles west of the last-mentioned locality, large micas up to 10 ins. in length are found. These occur in pegmatite veins, but the situation is further from the road.

COMPOSITION OF THE PEGMATITE VEINS OF WEST SUTHERLAND.

Proportions of quartz and felspar.

The pegmatite material consists predominantly of quartz and felspar. Iron-bearing minerals, such as biotite and hornblende, are present, but generally constitute less than 1 or 2 per cent., and though the proportion may sometimes reach 5 per cent., it is only in certain infrequent bands. Where the pegmatites are uncrushed, these ferromagnesian minerals (which tend to be associated with the plagioclase felspars) could be hand-picked from the quarried material.

Throughout some thin veins, and in parts of others, the quartz tends to form knots and strings, which may form from one-fifth to one-third of the whole vein. In these cases the felspar often occurs in rather large crystals, generally free from quartz intergrowths, but as a rule the felspar and quartz are intergrown and form the rock known as 'graphic granite.'

It, therefore, becomes of interest to consider whether graphic structures are accompanied by a constant proportion of quartz to felspar. According to Bastin,[1] the proportion is fairly constant and is not dependent on coarseness of grain, this conclusion being based on four analyses of graphic granite from pegmatites, the average composition of which is quartz 24·8 and felspar 75·2 per cent. The figures given by Vogt[2] are: quartz 27·5 and felspar 72·5, while the average composition of three graphic granites

[1] *Bulletin U.S. Geol. Surv.* 445 (1911), pp. 39–43, 123–125.

[2] *Silikatschmelzlösungen* II (1904), pp. 120, 121; *Tscherm. Min. Petr. Mitth.* (2), xxv (1906), pp. 361, 362, 383–385.

analysed in the laboratory of the Geological Survey[1] is quartz 26·9 and felspar 73·1 per cent. These are all average values, the figures in particular analyses varying between the extremes—quartz 17·65 and felspar 82·35; quartz 39·0 and felspar 61·0. Taking the least favourable of the above averages, we may estimate the composition as quartz 27·5 per cent. to felspar 72·5 per cent.

The amount of potash in potash-felspar.

It has already been seen in describing the felspars that various causes operate to reduce the percentage of potash in orthoclase and microcline below the theoretical maximum value, 16·9, and that accordingly the potash-content in the actual felspars of pegmatites must be estimated from analyses.

Four analyses of microcline from pegmatite veins in Sutherland[2] give for the average value of K_2O 12·81 per cent. Similarly the average in eight analyses[3] of potash felspars actually wrought in the United States is 12·82 per cent.

It will, therefore, probably be safe to take 12·81 per cent. of K_2O as the value to be expected from the potash felspars of the pegmatites.[4] This allows for the presence of dissolved and intergrown soda-felspar, but does not allow for separate crystals of soda-felspar, nor for any quartz, intergrown or otherwise.

The potash-content of the pegmatite.

From an inspection of the pegmatites at sixteen different localities in Sutherlandshire, it would appear that potash-felspar (microcline), probably including some perthitically intergrown soda-felspar, makes up about 72 per cent. of the total felspar present in the rock.

In certain cases the potash-felspar might be separated from the soda-felspar by hand-picking, but in the case of naturally crushed pegmatites this would not be possible, because the crushing has caused too intimate a mixture of the minerals.

The average percentage of potash in potash-felspars of this district is estimated to be 12·81 (this value allowing for dissolved and intergrown soda-felspar). In an intergrowth of any felspar with quartz to form graphic granite, the felspar forms about 72·5 per cent. of the whole. Therefore, the average K_2O in intergrowth of quartz with potash-felspar is $12{\cdot}81 \times {\cdot}725 = 9{\cdot}28$ per cent. This estimate agrees with the average of the three analyses of this intergrowth made in the Survey laboratory,[5] namely, 9·17.[6] The calculation is based on the supposition that all free soda-felspar has been picked out. When this cannot be done, since the potash-felspar forms on an average about 72 per cent. of the whole felspar,

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[1] *See* Analyses, p. 13, Nos. 1-3.

[2] Heddle, 'Mineralogy of Scotland,' vol. ii, p. 4.

[3] E. S. Bastin, *Bulletins of United States Geological Survey*, 315, pp. 390, 396, Nos. 1, 3, 4; 420, p. 9, No. 3: *id.*, *Min. Res. of United States* (1906), p. 1257, Nos. 2, 5, 6, and 11.

[4] The potash contained in plagioclase is, of course, negligible, see p. 1.

[5] Page 13, Nos. 1–3.

[6] The average of four similar intergrowths of quartz and potash felspar from American pegmatite quarries is 8·98. Bastin, *Bulletin of United States Geological Survey*, 420, p. 14, Nos. 1 to 4.

the reduced figure for the K_2O percentage would be, in the Scottish pegmatites, about $9{\cdot}28 \times {\cdot}72 = 6{\cdot}68$. This may be expected as an approximate value for the bulk of any large vein. An analysis of one specimen of such a vein, containing both soda- and potash-felspars, gave 5·77 per cent. of K_2O, a figure which is probably rather below the average (Analysis No. 4).

Some improvement could be effected by even partial sorting, and suitable choice of a site for a quarry in uncrushed rock might raise the average value to 9·28 per cent., but a value of 12 per cent. of potash would probably be attainable only under exceptionally favourable circumstances.

It has been seen that the average percentage of potash (K_2O) in the west of Sutherland pegmatites is about 6·25; and that after removal of the free soda-felspars it might rise to 9·25. The proportion of quartz varies from 22 to 39 per cent., as shown below.

American spars, which in some cases may have been freed from quartz before analysis, show the following percentages[1]:—

	K_2O.	Na_2O
No. 1 Grade, Richardson's Quarry, Bedford, Ont.	12·24	2·56
,, ,, Maine Felspar Co.'s Quarry, Auburn, Me.	10·26	4·08
No. 3 ,, Kinkle's Quarry, Bedford, N.Y. ...	5·24	3·74

No. 1 Grade spars, used for the finest pottery, should contain less than 5 per cent. of free quartz; No. 2 (or Standard) Grade may contain upwards of 20 per cent.; and No. 3 Grade includes the spars with considerably more than 20 per cent. It appears, therefore, that the best pegmatites from West Sutherland would fall into No. 2 Grade, but that the bulk would yield a No. 3 Grade spar.

Analyses.

The following partial analyses of felspathic rocks were made in the laboratory of the Geological Survey:—

	Percentages by Weight.			
	Found.		Calculated.	
	K_2O	Na_2O	Felspar.	Quartz, &c. (by difference).
1. Graphic granite ...	8·73	2·12	69·7	30·3
2. ,, ,, ...	9·69	2·39	77·7	22·3
3. ,, ,, ...	9·09	2·11	71·7	28·3
4. Pegmatite, sheared ...	5·77	3·12	60·7	39·3
5. Ground spar, reputed to be Swedish ...	7·09	3·44	71·2	28·8

(1) Sixty yards S.W. of sharp road bend at W. end of Loch na h-Ula, Laxford (A in Fig. 1). This specimen was potash-felspar intergrown with quartz, and contained a very little visible graphic soda-felspar as well. The potash-content is what might be expected, on an average, in working only the richest portions of pegmatite.

(2) 650 yards W. 18° N. of summit of Beinn Ceannabeinne, Durness (B in Fig. 2). A cleavage portion of a single crystal of microcline intergrown with quartz.

(3) 300 yards S.S.E. of sharp road bend at Sangobeag, Durness (C in Fig. 2). This specimen consisted wholly of microcline and quartz graphically intergrown.

Nos. 2 and 3 were specimens of probably the best material obtainable from the pegmatites.

(4) Half a mile W.N.W. of the summit of Beinn Ceannabeinne, Durness (A in Fig. 2). A sheared pegmatite, in which both soda and potash felspars were

[1] Bastin. *Bulletin of United States Geological Survey*, 445 (1911), pp. 51, 123.

present. The percentage of potash is probably a little below the average which would be obtained when working the whole of any large mass of pegmatite in Sutherland.

(5) This was a commercial spar, said to be Swedish, the use of which for making cement, after extraction of potash, was in contemplation.

SOME PEGMATITE-VEINS IN CORNWALL.

Roche Felspar Works, Tresayes Downs, Roche, Cornwall (abandoned).

Maps: One-inch Geological Sheet 347; six-inch Cornwall xli. S.E. Latitude 50° 23′ 30″. Longitude 4° 49′ 12″.

Geology of Bodmin and St. Austell, *Mem. Geol. Surv.*, 1909, pp. 61, 62.

"At Tresayes Downs there is a wide extremely coarse pegmatite vein in the Killas a few yards from the margin of the granite. It consists mainly of enormous orthoclase crystals, roughly parallel and arranged vertically, some of which are graphically intergrown with quartz. Some quartz occurs interstitially, frequently associated with tourmaline and a little fluorspar. There is also a little pale mica. The vein has a north and south direction nearly parallel with the margin of the granite at this place, and is nearly 50 yards in width. The vein was formerly worked for felspar for use in glass making, but the work was abandoned about 1880."

The felspar was analysed by J. A. Phillips, who published the following results. (*Phil. Mag.*, Feb., 1871.)

SiO_2	65·00	..... 65·33
Al_2O_3	19·00	..... 19·16
Fe_2O_3	·50	..... ·50
CaO	1·57	..... 1·68
MgO	trace.	..... trace.
K_2O	10·37	..... 10·37
Na_2O	2·40	..... 2·40
H_2O	·83	..... ·50

From the old workings there are about two miles of good road to Roche Station, on the Great Western Railway, Newquay branch.

The vein has not been worked out, but the quarry is flooded. As it consists mainly of felspar it would possibly repay working expenses.

Collins notes the occurrence of a pegmatite vein on the western side of Kernick Hill also, in the Treviscoe valley[1]. The locality is near the Chacewater and Newquay Railway in the six-inch map, Cornwall 50 N.W.

In the Land's End granite there are pegmatite-veins at Lamorna (small), in the Carnmenellis granite, near Pontsanooth, in the Bodmin Moor granite, near St. Breward, and at the wolfram works at Buttern Hill and Cannaframe, in Altarnun. In the Dartmoor Mass pegmatites occur in various places to the south-west of Widecombe; the felspar often form lumps 2 to 3 ins. in length, but many are slightly stained by iron-oxide.

In the Bodmin Moor, Land's End, and St. Austell granites, in addition to the potash contained in the felspar, there is a percentage of about 8 to 10 in the biotite.

[1] J. A. Collins, 'The Hensbarrow Granite District,' 1878, p. 9.

CHAPTER III.—PHOSPHATE OF LIME.

INTRODUCTION.

Phosphoric acid in various combinations occurs in certain minerals, and as phosphate of lime in rocks of indefinite composition, such as phosphatic nodules and phosphatised organisms (popularly known as 'coprolites'), phosphatic chalk and phosphorite (massive apatite). In Britain phosphatic nodules and phosphorite have been worked, but the industry became extinct in 1909, as a result of the importation of cheaper phosphates and the utilisation of basic slag.

Phosphatic nodules have been dug in the Crag, the Chloritic Marl and Upper Greensand, the Gault and the Lower Greensand. A bed of phosphorite has been worked in the Ordovician rocks of Montgomeryshire. Phosphatic Chalk occurs in limited quantities in England, but has not been worked. Though the more readily accessible parts of the phosphatic deposits have been dug out, there undoubtedly remain considerable reserves, which would be commercially available under suitable conditions as regards cost of working and price.

TREATMENT AND USES.

Phosphate of lime being insoluble, the raw material is first reduced to an extremely fine powder, and then treated with sulphuric acid, with the result that a soluble superphosphate is produced. Of the English deposits Cambridge 'coprolites' contained 55-60 per cent. of tricalcic phosphate without an undue admixture of ingredients, such as alumina and iron, prejudicial to the production of soluble phosphate. The Suffolk 'coprolite' contained 55 per cent. of the phosphate and more ferric oxide, and the Bedfordshire (Lower Greensand) 'coprolite' showed a still larger proportion of ferric oxide.[1] The soluble phosphate is used as a fertiliser of the soil.

STATISTICS.

Output and value of Phosphate of Lime in the United Kingdom, 1874 to 1913.

Year.	Quantity. Tons.	Value. £	Year.	Quantity Tons.	Value. £	Year.	Quantity Tons.	Value. £
1873	No returns.	—	1886	20,000	31,500	1900	620	1,085
			1887	9,894	15,830	1901	79	136
1874	149,654	388,290	1888	22,500	43,312	1902	86	109
1875	250,122	628,000	1889	20,000	38,250	1903	70	87
1876	258,150	625,000	1890	18,000	29,500	1904	58	87
1877	69,006	200,000	1891	10,000	20,000	1905	Nil.	—
1878	54,000	150,000	1892	12,200	22,250	1906	Nil.	—
1879	34,000	73,750	1893	3,300	5,771	1907	32	46
1880	30,500	70,950	1894	700	1,277	1908	9	14
1881	31,500	86,628	1895	2,500	4,375	1909	4	6
1882	49,550	97,600	1896	3,000	5,250	1910	Nil.	—
1883	49,580	101,729	1897	2,000	3,500	1911	Nil.	—
1884	51,866	103,976	1898	1,550	2,713	1912	Nil.	—
1885	30,000	50,000	1899	1,446	2,529	1913	Nil.	—

[1] 'A Dictionary of Applied Chemistry,' by E. Thorpe, vol. ii, 1912, pp. 542, 544.

Total imports of Phosphate of Lime, 1882 *to* 1913.

	Tons.	Value. £		Tons.	Value. £		Tons.	Value. £
1882	199,428	613,198	1893	323,527	594,467	1904	419,270	620,066
1883	246,945	813,825	1894	380,269	723,205	1905	420,988	616,131
1884	219,225	643,851	1895	359,659	633,314	1906	442,970	678,696
1885	238,572	628,027	1896	291,314	465,931	1907	505,671	826,974
1886	223,111	526,885	1897	324,788	491,813	1908	529,135	916,422
1887	283,415	614,088	1898	330,610	502,422	1909	451,807	747,367
1888	257,886	544,919	1899	420,108	682,940	1910	455,593	722,508
1889	304,953	703,704	1900	355,502	588,698	1911	493,415	779,706
1890	343,501	849,452	1901	354,890	551,717	1912	520,267	840,996
1891	256,772	628,395	1902	364,859	553,922	1913	539,016	874,166
1892	314,130	665,689	1903	392,782	560,707			

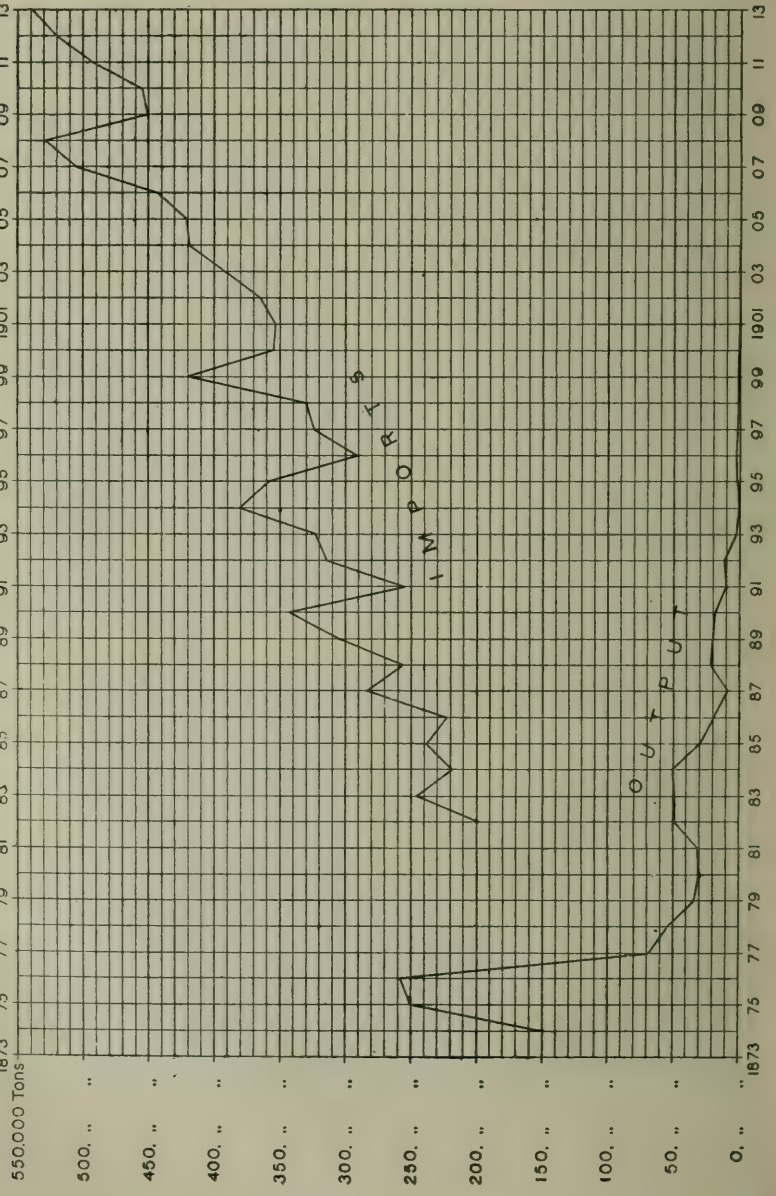

FIG. 3.—ANNUAL OUTPUT OF PHOSPHATE OF LIME IN GREAT BRITAIN, AND ANNUAL IMPORTS.

Sources and value of imports of Phosphates of Lime, 1912 *and* 1913.
From the Home Office statistics.

Countries whence consigned.	1912.		1913.	
	Quantity. Tons.	Value	Quantity. Tons.	Value.
		£		£
Germany	5,578	15,214	14,168	37,990
Netherlands	15,518	30,772	24,347	50,565
Belgium	56,417	85,756	63,969	108,608
France	20,160	27,332	10,166	12,920
Tunis	204,922	270,451	189,555	249,732
Algeria	40,773	61,312	44,996	66,598
Egypt	—	—	15	30
U.S.A.	157,962	306,495	177,330	314,246
Dutch W. India Isles	4,102	6,859	4,476	8,377
St. Pierre and Miquelon... ...	4,135	12,170	—	—
French Possessions in Pacific ...	3,400	7,951	2,633	6,582
French Guiana	1,600	4,800	1,615	3,230
Colombia	3,000	4,905	—	—
Other Pacific Isles (British) ...	2,700	6,979	5,744	15,283
British W. India Isles	—	—	2	5
Total	520,267	840,996	539,016	874,166

CHAPTER IV.—PHOSPHATE OF LIME CONTINUED.

RED AND CORALLINE CRAGS.

The strata which yield the phosphatic nodules, formerly worked in the Pliocene Beds of Suffolk, lie at the base of both the Red and Coralline Crags, but were dug at the base of the latter in one place only and then not profitably. They are of a conglomeratic character and contain a miscellaneous collection of various rocks in addition to phosphatic nodules, phosphatised shells, bones, teeth and fragments of wood. In places they may be represented only by a line of nodules, but more usually they are 10 or 12 inches, or, exceptionally, 18 inches thick.

They were dug at the outcrop and followed in open pits until the thickness of cover became prohibitive. More than 30 feet was removed at Foxhall, but this was exceptional. The cover, consisting of the overlying Crag, was removed in stages, thrown back, and the land restored; the bed itself was screened and hand-picked.

The phosphates have a smooth, almost waxy, surface, and a yellowish-brown tint which distinguishes them from the 'coprolites' of the Upper and Lower Greensands. They are hard and grind to a yellowish-red powder. This composition is illustrated by the following analyses by Dr. Voelcker[1]:—

Detailed composition of Suffolk Coprolites.

	No. 1.		No. 2.
Moisture and water of combination with a trace of organic matter	5·76	...	2·53
Lime	40·70	...	38·20
Magnesia	·34	...	1·34
*Phosphoric acid	28·32	...	24·24
Oxide of iron ... ... } Alumina ... ... }	4·87	...	{ 4·81 / 3·72
†Carbonic acid	5·08	...	5·37
Sulphuric acid	·87	...	1·40
Potash	·78	...	·56
Soda	·25	...	1·18
Chlorine	traces.	...	·07
Fluorine and loss	3·02	...	4·31
Insoluble siliceous matter	10·01	...	12·27
	100·00	...	100·00
* Equal to tribasic phosphate of lime (bone-earth)	61·30	...	52·52
† Equal to carbonate of lime	11·64	...	12·20

"No. 1, it will be seen, is a very superior sample; No. 2 represents a good average sample of Suffolk coprolites."

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[1] On the Chemical Composition and Commercial Value of Norwegian Apatite, Spanish Phosphorite, Coprolites and other Phosphatic Materials used in England for Agricultural Purposes.—*Journ. Roy. Agric. Soc.*, vol. xxi, 1860, p. 360.

The commercial value of the Suffolk phosphates came under consideration in 1845, and they were first dug in 1847. In 1854 the Cambridge coprolites came into competition with them. The following estimates of output were furnished by Mr. W. Colchester to the Geological Survey Memoir on the Pliocene Deposits of Britain, published in 1890.

Estimates of Output of Phosphates in Suffolk.

Year.	tons.	Year.	tons.	Year.	tons..	Year.	tons.
1847 ...	500	1855 }	Average	1877 ...	10,000	1884 ...	7,800
1848 ...	1,000	1856 }	about	1878 ...	10,000	1885 ...	6,000
1849 ...	3,000	1857 }	9,000	1879 ...	4,000	1886 ...	4,000
1850 ...	5,000	1858 ...	10,000	1880 ...	5,000	1887 ...	2,000
1851 ...	6,000	1859 }	Average	1881 ...	5,500	1888 ...	3,000
1852 ...	8,000	to }	about	1882 ...	5,500	1889 ...	5,000
1853 ...	10,000	1876 }	9,000	1883 ...	5,500		
1854 ...	12,000						

The following list gives the localities at which phosphatic nodules have been worked at the base of the Crag. North of the R. Deben:—Bawdsey, Boyton, Butley, Capel, Shottisham, Sutton. South of the R. Deben:—Felixstowe, Foxhall, Hemley, Ipswich, Little Oakley, Newbourn, Orford, Trimley, Waldringfield, Walton, Wrabness

(For references to Survey Memoirs, see p. 24.)

CHALK.

Phosphatic chalk occurs in the Upper Chalk at Taplow, in Buckinghamshire. There are two phosphatic bands, 8 and 4 ft. thick respectively, with about 27 ft. of ordinary chalk between.[1] In composition they correspond closely with the phosphatic chalk of Belgium, as shown in the following analyses:—

	Ciply Phosphatic Chalk (Belgium). Mr. Petermann.		Taplow Phosphatic Chalk Mr. Player.
Moisture	—	.....	·7
Organic matter	2·83	.....	2·3
Lime	53·24	.....	53·7
Magnesia	0·12	.....	—
Iron oxide ... ... } Alumina ... ... }	1·01	.....	0·1 0·8
Potash ... ... } Soda ... ... }	0·19	.....	0·1 0·2
Carbonic acid	28·10	.....	28·7
Sulphuric acid	0·89	.....	·7
Phosphoric acid	11·66	.....	11·6
Silica and sand	1·96	.....	0·5 (Silicic acid.)
Fluorine ... ... } Chlorine ... ... }	traces.	.....	0·7 traces.
	100·00	.....	100·1

The Taplow phosphatic chalk is a friable brown rock, easily separable by washing into a brown sand and a white chalk-mud. The brown sand consists of more or less perfectly phosphatised foraminifera, small fragments of shell and minute oval pellets which appear to be the exuviæ of small fishes. Neither as regards its extent nor its quality has it been regarded as worth working.

[1] Strahan. *Quart. Journ. Geol. Soc.*, vol. xlvii, 1891, p. 356.

Similar phosphatic chalk, in small quantity, has been noted in Sussex[1] and Berkshire.[2]

CHLORITIC MARL.

Cambridgeshire, Bedfordshire and Hertfordshire.—The band containing phosphatic nodules, or 'coprolites,' in these counties, lies at the base of the Chalk Marl and corresponds in position to the Chloritic Marl, though it has been commonly known as the 'Cambridge Upper Greensand.' The productive part of the band is about 8 to 12 ins. thick, and was reached by digging away the cover of Chalk Marl, to a thickness which might amount to 20 ft. It rests upon a clean surface of Gault, with undulations which have resulted from erosion.

The matrix, a sandy marl crowded in the lower part of the band with grains of glauconite, was removed by raking under water in a circular mill. The nodules are dark-brown or nearly black, but of a light-brown or buff colour inside. They are casts of bones and teeth of reptiles or fishes, mollusca, echinoderms, crustacea, corals and sponges. True coprolites, that is, the exuviæ of fishes and reptiles, are rare.

About £140 an acre was paid for the privilege of digging the 'coprolites,' and the yield per acre was on the average 300 tons. The price has reached 50s. a ton. The value of the nodules was recognised in 1854 and the diggings have extended from Cambridgeshire to Hitchin, in Hertfordshire, but the industry is now extinct.

A good aggregate sample of Cambridge nodules contains from 56 to 58 per cent. of tribasic phosphate of lime. Commercial analyses often indicate a higher percentage, but this, according to Dr. Voelcker, is due to the inclusion of 3 to 4 per cent. of fluoride of calcium.[3] In the following analyses Dr. Voelcker has determined the percentage of phosphoric acid, and calculated the amount of tribasic phosphate to which it is equivalent.

Detailed Composition of Average Samples of Cambridgeshire Coprolites.

	No. 1.	No. 2.	No. 3.
Moisture and organic matter ...	4·63	4·01	3·52
Lime	43·21	45·39	46·60
Magnesia	1·12	·48	1·06
Oxide of iron	2·46	1·87	2·08
Alumina	1·36	2·57	1·41
*Phosphoric acid	25·29	26·75	27·01
†Carbonic acid	6·66	5·13	5·49
Sulphuric acid	·76	1·06	not dtd.
Chloride of sodium	·09	traces.	traces.
Potash	·32	·84	not dtd.
Soda	·50	·73	,,
Insoluble siliceous matter	8·64	6·22	6·04
Fluorine and loss	4·96	4·95	6·79
	100·00	100·00	100·00
* Equal to tribasic phosphate of lime	54·89	57·12	58·52
† Equal to carbonate of lime ...	15·13	11·66	12·47

[1] Strahan. *Quart. Journ. Geol. Soc.*, vol. lii, 1896, p. 463.
[2] White and Treacher, *ib.*, vol. lxii, 1906, p. 499.
[3] Fisher. *Quart. Journ. Geol. Soc.* vol. xxix, 1873, p. 52. *Journ. Roy. Agric. Soc.*, vol. xxi, p. 358.

The excavations for the 'coprolites' were confined to the outcrop of the bed and to the neighbouring ground in which the overlying chalk-marl did not exceed 20 feet in thickness. The greater number lay in Cambridgeshire at the following localities:—Abington, Barrington, Bassingbourn, Burwell, Bottisham, Cherry Hinton, Coldham, Coton, Duxford, Fen Ditton, Grantchester, Great Shelford, Guilden Morden, Harlton, Harston, Haslingfield, Hauxton, Horningsea, Litlington, Melbourn, Meldreth, Molden, Orwell, Quy-cum-Stow, Shepreth, Soham, Sutton, Swaffham, Trumpington, Whaddon, Wicken, Wimpole, Whittlesea. In Bedfordshire there were workings at Shillington and other places, and in Hertfordshire at Ashwell and Hitchin.

(For references to Survey Memoirs, see p. 24.)

Hampshire and Surrey.—In the Isle of Wight phosphatised casts of shells occur in the Chloritic Marl. Attempts were made to work them in 1851, but were soon abandoned. The nodules are of a pale-brown colour, low specific gravity, and yield a considerably lower percentage of phosphoric acid than the 'Cambridge coprolites.'[1] In Surrey phosphatised fossils are abundant towards the bottom of a marly green sand, which lies at the top of the Upper Greensand. They constitute 61 per cent. of the bulk of the bed at that level, and have been largely worked near Farnham. Nodules from Dippen Hall were found by Prof. Way to contain 27·6 per cent. of phosphoric acid.[2]

Gault.

Phosphatic nodules are of frequent occurrence in the Gault, but are seldom sufficiently concentrated in beds to pay for extraction. In Kent a band of nodules occurs at the base of the Upper Gault, and in Buckinghamshire nodules have been worked from a seam of green sand, which lies 150 feet above the base of the Gault, and is taken as the base of the Upper Gault. At Puttenham (Herts.) this band was worked in 1874, and showed an upper part of sandy clay with some nodules and a lower part of dark-green sand full of rolled black nodules, the total thickness being 1½ feet. The same seam was worked at Cheddington and Hopton, and has been seen near Egginton, in Bedfordshire. A nodule-bed which lies at the base of the Gault is more persistent. It is of constant occurrence around the Weald except for some 10 or 12 miles in Sussex, and has been worked near Farnham, Folkestone and Wrackleshamm. At Cheriton, near Folkestone, the nodules occur in two beds separated by 2 feet of clay; the upper band 3 to 6 inches and the lower 12 to 15 inches in thickness. All the material was dug out in trenches and the nodules picked out by hand. In good samples phosphoric acid ranged up to 25 per cent.[3]

In Buckinghamshire a bed of nodules, lying 20 or 30 feet above the base of the Gault, was worked between 1875 and 1884 at Towersey, and between Ford and Moreton. At Ford the seam is

[1] 'The Geology of the Isle of Wight' (*Mem. Geol. Survey*), 2nd. Ed., 1889, pp. 253, 254.

[2] *Journ. Roy. Agric. Soc.*, vol. ix, p. 71.

[3] 'The Geology of the Weald' (*Mem. Geol. Survey*), 1875, pp. 389, 390.

3 to 4 inches thick and consists of phosphatised shells and lumps of 'coprolite' embedded in a stiff calcareous clay. The nodules are harder and larger than those of the Cambridge Greensand.[1] The same seam was worked about the year 1885 south of Bishopstone.[2] In Bedfordshire it was worked at Campton, near Shefford. The nodules lay in a bed of grey clay and were scattered through a thickness of 9 to 24 inches. At Upware, in Cambridgeshire, a nodule-bed about 5 in. thick, occurs at or close to the base of the Gault, and at West Dereham, in Norfolk, a bed 9 in. thick occupies a similar position. Both have been worked.[3]

(For references to Survey Memoirs, see p. 24.)

LOWER GREENSAND.

Phosphatic nodules are of sufficient abundance to have been worth working in parts of the Lower Greensand of Surrey, Buckinghamshire, Bedfordshire, Cambridgeshire and Yorkshire.

In Surrey the nodules occur in the uppermost part of the Folkestone Beds and have been worked at Farnham.

In Bedfordshire the nodule-bed varies from a few inches up to 2 feet in thickness and lies in, or often at the base of, the Lower Greensand. It is composed of nodules and pebbles in a matrix of ferruginous sand. The nodules consist of casts of fossils and lumps of phosphatic matter, are light-brown outside, but much darker in the interior. They range in size up to that of a hen's egg.[4]

The following analyses of the best average samples at Sandy were made by Dr. A. Voelcker, and are quoted from a paper by the Rev. P. B. Brodie.[3]

	Average samples of Siftings from layers at 1 and 2 feet.	Washed Coprolite from another spot.
Water of combination	5·17	5·67
*Phosphoric acid	22·39	15·12
Lime	32·73	26·69
Magnesia, alumina and fluorine (by difference)	6·64	4·51
†Carbonic acid	3·06	2·18
Oxide of iron	8·08	20·61
Siliceous matter	21·93	25·22
	100·00	100·00
* Equal to tribasic phosphate of lime (bone-earth) ...	48·51	32·76
† Equal to carbonate of lime	6·95	4·95

The paper referred to is the first published notice of the occurrence of this nodule-bed in Bedfordshire. The occurrence was discovered about 1864, and digging was commenced before 1866. The bed has been worked in Cambridgeshire at Haddenham, Stretham, Upware, and Wicken; in Bedfordshire at Ampthill, Astwick, Gravenhurst, Potton, Sandy, and Woburn; in Buckinghamshire at Bishopstone and Brickhill.

(For references to Survey Memoirs, see p. 24.)

[1] From notes furnished by the late W. Keeping.
[2] 'Cretaceous Rocks of Britain' (*Mem. Geol. Survey*), vol. i, 1900, p. 277, *et seq.*
[3] *Geol. Mag.*, vol. iii, 1866, p. 154.
[4] The Potton and Wicken Phosphatic Deposits by J. J. H. Teall, 1875. *Cambridge.*

In Yorkshire a 'coprolite-bed' occurs at the base, and another 30 feet above the base, of the Speeton clay. The lower bed was worked by adits in the cliff for a short time prior to 1869, but, being only 5 inches thick, was scarcely remunerative. The nodules were almost black, and contained much pyrites. Washed samples yielded from 57 to 61 per cent. of phosphates. About 500 tons were raised annually.[1]

In Lincolnshire small phosphatic nodules occur abundantly in several localities at the base of the Spilsby Sandstone, and in some places at the base of the Carstone, but have nowhere been worked. Some of them are dark, and contain from 21 to 23·5 per cent. of phosphoric acid (corresponding to 46·6 and 51·4 of phosphate of lime); others are of lighter colour and contain much sand.[2]

Ordovician.

A bed of phosphorite[3] was discovered in the Ordovician rocks near Llanfyllin, in Montgomeryshire, in 1863, and was worked from 1864 to 1884. It lies at the top of the Bala Limestone and has been proved to extend from Cwmgwnen, 5 miles west of Llanfyllin, north-eastwards to Pen-y-garnedd, and south-westwards to Pwll-y-wrach. It has been recognised in the Berwyn Mountains at Craig Rhiwarth, and at Blaen-y-cwm; it occurs also at Green Hall Park, about 1 mile south-east of Llanfyllin, and at Llan-y-mawddwy, in eastern Merionethshire.[4]

The bed varies in thickness from 10 to 15 inches, and has a black colour, through the presence of graphite, which was prejudicial to its sale. It presents the appearance of a number of concretions cemented together by a black matrix. In good samples the concretions yielded an analysis which indicated 64 per cent. of tribasic phosphate, as compared with about 46 per cent. in the bulk of the rock.[5]

Mines were opened at Cwmgwnen, Pen-y-garnedd, Llanfyllin. Craig Rhiwarth, and elsewhere. It appears that the removal of worthless matter from the phosphorite cost 3s. a ton.

No records exist of the amount raised before 1874. The annual output from that year until the mines were closed is given in the Mining Records and the Home Office Reports, as follows:—

Annual output of Phosphorite in Montgomeryshire.

	Tons.	Value in pounds.		Tons.	Value in pounds.
1874	504	500	1880	—	—
1875	122	—	1881	60	—
1876	209	250	1882	50	100
1877	6	7½	1883	80	104
1878	15	30	1884	66	76
1879	24	48			

[1] J. W. Judd. *Quart. Journ. Geol. Soc.*, vol. xxiv, 1868, p. 250.

[2] 'The Geology of East Lincolnshire' (*Mem. Geol. Survey*), 1887, p. 134. and 'The Geology of the Country around Lincoln' (*ib.*). 1888. pp. 108–114.

[3] D. C. Davies. *Quart. Journ. Geol. Soc.*, vol. xxxi. 1875. p. 357.

[4] W. Keeping. *Quart. Journ. Geol. Soc.*, vol. xxxvii. 1881, p. 162.

[5] For analyses see A. Voelcker, *Brit. Assoc. Rep.* for 1865, Trans. of Sects., p. 37.

A statement in the Mineral Statistics for 1876 that 20 tons 0 cwt. 3 qrs. of phosphate of lime were raised in that year at the Pennant Mine in Flintshire appears to be incorrect. That amount of barytes was raised in 1876, but no phosphate has ever been produced from the Pennant Mine.

Further particulars and local details of 'coprolite' workings will be found in the following memoirs of the Geological Survey:—

'Crag' Phosphates.

'Geology of the Country around Ipswich, Hadleigh and Felixstowe' (1885): pp. 27–28, 30–71, 101–105.
'Geology of the Eastern End of Essex' (1877): pp. 13–14, 22–24.
'The Pliocene Deposits of Britain' (1890): pp. 6–18.

'Cambridge Greensand,' Gault and Lower Greensand Phosphates.

'Geology of the neighbourhood of Cambridge' (1881): pp. 18, 19, 24–38, 126–128.
'Geology of parts of Cambridgeshire and Suffolk (Ely, Mildenhall, Thetford)' (1891): pp. 20–29, 36, 37, 103–105.
'Geology of S.W. Norfolk and N. Cambridgeshire' (1893): pp. 13, 14, 23, 24.
'The Cretaceous Rocks of Britain, vol. 2, Gault and Upper Greensand' (1900): pp. 427–433.

CHAPTER V.—ALUM SHALES.

England.

Alum-shales were formerly obtained from several formations, in several counties, but the industry is now confined to the Coal Measure shales of the West Riding of Yorkshire. There the shales are worked in association with coal by the Rainstorth Colliery Company at Thorpe near Rotherham, by the Primrose Main Colliery Company and the New Wallsend Main Colliery Company at Smithies near Barnsley, and by the Central Silkstone Company near Barnsley; also at the Woolley (Scarishaw) Mine near Darton, and the Haigh Colliery near Barnsley, in both cases by Fountain and Barnby, Limited.[1] They have been worked in northern and eastern Lancashire also, but the last return for that county was 3,016 tons in 1906. The supply of shale is practically inexhaustible.

The shale is calcined, with the object of oxidising iron pyrites and forming sulphates of iron and alumina. The calcined shale is steeped in shallow pits, and the liquor, after sufficient concentration, is treated with potassium chloride, to form protochloride of iron and alum.

The shales mentioned above all belong to the Coal Measures, but Tertiary Clays, the Kimmeridge Clay and the Lias have all yielded alum.

Tertiary Clay.—Near Corfe Castle the white and red mottled clays of the Bagshot series are mixed for making pottery. "The water which filtered through the spoil-banks of the clay-pits is highly charged with sulphates, and from the presence of potash, was formerly used for the manufacture of alum. The presence of iron, however, spoils it for that purpose."[2]

Alum was formerly manufactured in the Isle of Wight "from the clays of Alum Bay, and as early as 1579 at works in Parkhurst Forest. The Crown used formerly to monopolise the whole of the alum, and proper people were appointed to gather and preserve it for Government."[3]

Kimmeridge Clay.—In the early part of the 18th century alum was manufactured in Kimmeridge Bay. Subsequently the works were seized by the Crown, and in 1748 there remained only heaps of shale to mark their position.

Lias.—During the 18th century the Upper Lias of the neighbourhood of Whitby formed one of the principal sources of alum.[4]

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[1] All the collieries mentioned are situated in the one-inch Geol. Map (Old Series) Sheet 87 S.W.

[2] J. Trimmer. *Journ. Roy. Agric. Soc.*, vol. xvi, 1855, p. 131.

[3] 'Geology of the Isle of Wight' (*Mem. Geol. Survey*), 2nd. Ed., 1889, p. 252.

[4] 'The Geology of the Country between Whitby and Scarborough' (*Mem. Geol. Survey*), 2nd Ed., 1915, p. 125.

There were works of some magnitude at Peak, Stoupe Brow, Saltwick, Landsend and Lythe, Kettleness, Boulby, Lofthouse and Eskdale.

The total output has fluctuated considerably within recent years, as shown by the following returns:—

	Tons.		Tons.
1876	4,518	1905	7,131
1877	19,735	1906	9,454
1878	6,733	1907	1,499
1884	1,960	1910	6,674
1890	6,420	1911	10,516
1895	2,063	1912	11,258
1896	Nil.	1913	8,741
1898	13,617		

Scotland.

In Scotland alum has not been manufactured from alum shales for many years, though at one time this industry was carried on at several places.[1] Pyritous shales, which on suitable treatment yield alum, occur principally in the Carboniferous System, often in association with beds of coal which can be utilised in roasting the shale. At the base of the Carboniferous Limestone of Scotland there is an important limestone, the 'Hurlet,' which is underlain by an alum-shale and a coal-seam. These beds were worked in more than one place; and at Lennoxtown and at Hurlet, in Renfrewshire, they were used as sources of alum. An interesting account of the process employed at Hurlet is given in Williams' 'Mineral Kingdom' (2nd edit., 1810, pp. 315–319). He states that the coal, which is five feet thick, had been worked on an extensive scale, the excavations being over a mile long and nearly a mile broad. Between the coal and the limestone there is an alum-shale about ten inches thick. When the coal had been extracted the shale on the roof was allowed to fall, when, through the action of moisture and air, it swelled up and was covered by an efflorescence of salts. Williams considered that it required from ten to twelve years for the alum to form naturally. Large works for the extraction of alum were erected near Hurlet about the year 1800; previously there had been a small copperas works in the same district.

From the 'New Statistical Account of Scotland' vol. ii, 1845, p. 58) it seems that there was at one time an alum-works at Carriden, in Linlithgowshire. At Dysart, in Fife, there is a well, called the Alum Well, and its waters were used for medicinal purposes (*op. cit.*, vol. ix, p. 128).

Among the Silurian rocks of the South of Scotland pyritous shales are common, and at some localities, such as Moffat and Ferrytown of Cree, crystals of alum have been observed on their weathered surfaces, but there is no record of any attempt to prepare alum from these on a commercial scale.

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[1] For an account of the industry in 1876, *see* 'Notices of some of the Principal Manufactures of the West of Scotland,' Glasgow (Blackie and Son), 1876, pp. 225–7 (prepared for the meeting of the British Association at Glasgow in 1876).

CHAPTER VI.—PLUMBAGO OR GRAPHITE, MOLYBDENITE, CHROMITE, TALC AND STEATITE, DIATOMITE.

Plumbago or Graphite.

Plumbago has been worked in Cumberland, but not elsewhere in England or Wales. In Scotland it has been worked in several counties.

England.

Borrowdale Plumbago Mine (inactive).

Maps. One-inch Old Ser. Geological 101 S.E., New Ser. Ordnance 29; six-inch Cumberland 70 S.W. and 75 N.W. Latitude 54° 29′ 55″. Longitude 3° 11′ 5″.

Situated near Seathwaite, in Borrowdale.

The plumbago occurs in pipes, strings, and nests, in close connection with a dyke of highly altered diorite, which lies between two other masses of compact diabase intruded into the Borrowdale Volcanic Ashes. Nests of plumbago frequently occur in the altered diorite, and all stages may be seen, from diorite with a little graphite to a rock which is largely made up of impure graphite. The principal pipes, however, appear to have been associated with the compact diabase and the highly metamorphosed ashes. J. C. Ward[1] states that "the pipes themselves are seldom more than two or three yards in their longest diameter and one yard in their shortest, though extending to considerable depths; they often seem to come on very suddenly, and, while surrounded by the very compact diabase, are themselves made up of an irregular 'waddy' breccia, mingled with strings and bunches of quartz."

The mine was in operation towards the end of the 18th and the early part of the 19th centuries, but since 1833 little graphite has been obtained, although a fair amount of prospecting was done about 1875.

The graphite was worked from nine levels driven into the hillside. Sections and plans of the workings are given in the Geological Survey Memoir referred to above and in 'Mines and Mining in the Lake District,' by J. Postlethwaite, to which works reference should be made for further details. Pure Borrowdale plumbago in 1876 fetched 40s. per pound; from its peculiar state of aggregation, it was specially in request for making the best black-lead pencils.[2]

The dumps, which are fairly extensive, contain some impure graphite.

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[1] 'The Geology of the Northern Part of the Lake District' (*Mem. Geol. Survey*), 1876, p. 64.

[2] 'Metallurgy' (Fuels), J. Percy, 1875, p. 103.

Scotland.

Graphite is by no means a rare mineral in Scotland, though it has never been mined there on a large scale and all the old mines are now closed.

Among the rocks of the Scottish Highlands graphite-schists have a fairly wide distribution, especially in Banffshire, Aberdeenshire, and Perthshire. They are soft, dark grey, slaty-looking rocks, often fissile, and when handled they stain the fingers. The graphite occurs in minute dark scales, mixed with mica and quartz, and forms only a small percentage of the rock. Graphite-schists are found also at Loch Maree and in Inverness-shire. Occasionally graphite is visible as small bright grey scales in crystalline limestone, gneiss, and granite. The dark Silurian shales of the South of Scotland may also contain graphite in small quantity.

Of the localities in the Highlands where graphite has been mined, one of the most important is in Glen Strathfarrar. The old mine is situated on the north side of the River Farrar, 550 yards below the foot of Loch a'Mhuilinn. Heddle ('Mineralogy of Scotland,' 1901, vol. I., p. 2) states that "In 1818 five tons were extracted, which sold for £93 each; the cost of raising was £13 per ton." The vein is nearly vertical and runs in a north-east direction. Its thickness is very irregular. (Geology of the Country round Beauly and Inverness, *Mem. Geol. Surv.*, 1914, p. 99.)

At Invergarry, near the head of Loch Lochy, and about one mile from the Caledonian Canal, at the head of a rocky ravine on the west side of Leacann Doire Bannear, there is a vein of graphite said to be from 1 foot to 3 feet wide (Heddle, *loc. cit.*). About 2 tons were raised there in 1825. The graphite is of fairly good quality. This locality is not difficult of access, and it is possible that the vein would prove worth working.

Near Huntly graphite occurs at the old mines immediately below the bridge over the Deveron, on its south bank, and at its junction with the Bogie (Heddle, *loc. cit.*). Near the farm of Bodibae, in the Cabrach, Aberdeenshire, there is a vein of soft graphite several inches thick, and at the head of the Carvie Water there is a band of black schist included in diorite; it contains veins of graphite one to four inches thick. (Explanation of Sheet 75, *Mem. Geol. Surv.*, 1896, p. 34.)

Specimens of graphite from about twenty localities in Scotland may be seen in the Royal Scottish Museum, Edinburgh.

Where beds of coal have been penetrated by an intrusive igneous rock they are often greatly altered. In some places they are changed to a spongy mass resembling coke; in others they are converted into anthracite; but the extreme form of alteration seems to be the production of graphite at the expense of the coal. Mr. R. Dron (*Trans. Edin. Geol. Soc.*, vol. x., 1912, p. 25) records that bores recently put down in the Manor-Powis coalfield, near Stirling, passed through several seams of coal that had been altered in various degrees by the Abbey Craig dolerite-sill which lies beneath them. In one instance a thin seam in contact with the whin was converted into graphite.

The Craigman mine, Ayrshire, appears to be the only place in Scotland where graphite has recently been mined for economic use. Dr. C. T. Clough has recently visited this mine and prepared a report on it from which we take the following particulars: —

This mine, locally called the Waud Mine, is situated in one-inch Sheet 14 and six-inch map Ayrshire 41 S.W. It lies between 7 and 8 miles S.S.W. from Cumnock Railway Station, by the road, and much the same distance also, by the road, in a direction slightly south of west from New Cumnock Station. The mine consists of a short day-level with some side roads. It is reputed to have been worked on a small scale for about 100 years prior to 1848, when it was abandoned for a long period. The graphite is reported to have been carted to Keswick, to be used with the Borrowdale graphite. In 1908 the mine was reopened but soon abandoned. According to the Home Office returns 101 tons with a value of £101 were raised.

For full details of the occurrence of graphite reference should be made to a paper by Mr. John Smith.[1]

The graphite occurs in pockets of varying size and shape in an intrusive sill of whinstone (dolerite) 10 or 12 feet thick. A little within the mouth of the day-level the whin is seen overlying a seam of burnt columnar coal about 2 feet thick, and presumably the pockets of graphite represent portions which have been torn off by the whin, and being entirely surrounded by whin, have been more intensely heated. The larger pockets, according to Mr. Smith, contain also some coke, but a thin layer of massive graphite generally lies close above the whin.

Some of the holes from which the graphite was mined are more than a yard in length and breadth. Mr. Sanderson states that from one pocket he got as much as 15 tons of graphite, and at one end of it graphite is still visible. The pockets were irregular in size, shape and distribution, and have been sought for by short side roads in various directions. One, which is still visible, is 4 or 5 feet long in a vertical direction, and about 1 foot wide. It is crossed by a nearly horizontal vein of whinstone, 2 or 3 inches thick.

The mine has been worked for a distance of about 66 yards in a northerly direction. Near the end a fault cuts out both whinstone and graphite, but beyond the fault a thick splint coal was found according to Mr. Sanderson.

Analyses of the Craigman graphite differ greatly, the proportions of carbon ranging from 97·3 per cent. down to 57·2 per cent., possibly through the admixture of strings of whin. It is to be observed that the strings of whin show no chilling, and that the beds, probably representing blaes and sandy blaes, that overlie the whin, have been intensely altered and hardened. These observations support the supposition that pockets of graphite, etc., found within the whin have been subjected to unusually high temperatures. The graphite taken from the Craigman mine in 1908 was sold in Glasgow by ironfounders' blacking manufacturers.

[1] 'Charred Coal, with Graphite, and discovery of Diamonds in the Graphite, at Craigman, New Cumnock.' *Trans. Geol. Soc. Glasgow*, vol. x, 1895, p. 257.

Molybdenite.

The greater part of the molybdenum used in commerce is employed for the preparation of special varieties of steel, to which this metal imparts properties similar to those due to the presence of tungsten. A certain amount of molybdic acid is used for dyeing textiles, and, in the form of ammonium molybdate, as a chemical reagent for the estimation of phosphorus.

The principal ore is the sulphide (MoS_2), molybdenite, which contains, when pure, 60 per cent. of molybdenum. The mineral wulfenite ($PbMoO_4$), having the composition PbO 60·7 per cent., MoO_3 39·3 per cent., has also occasionally been obtained in marketable quantities. Molybdenite is a very soft mineral, of metallic lustre, and exhibiting an extremely easy cleavage which causes the crystals to divide into thin flakes when crushed. This fissibility leads to difficulty in the concentration of the poorer ores, although the density is fairly high (4·7), and, coupled with the irregular character of the deposits, has probably led to the small development of these ores in comparison with those of tungsten.

The output of molybdenite has been somewhat erratic and the statistics are probably incomplete. The following returns are given in the Home Office Reports:—

Year.	New South Wales.	Queensland.	Norway.	Total.
				Tons.
1911	21	99	2	122
1912	57	102	21	180

A sample of 66 tons was obtained from Natal in 1904.

These countries have been the chief sources since 1900. No record is given of any commercial production in England, but the occurrence of small quantities in Cornwall, Leicestershire and Cumberland and in Scotland, is recorded in the mineralogical text-books. The mineral is found in granite, pegmatite and adjoining rocks, and the deposits are of an extremely pockety nature; it has usually been encountered in the course of mining other ores, and it seems most unlikely that the production could be accelerated to any useful extent. The nearest foreign molybdenum-deposit is that in Norway.

The statistics indicate that by far the greater part of the world's supply of molybdenum is obtained from British Colonies. In addition to the Australian occurrences, numerous localities in Canada are discussed in detail by T. L. Walker;[1] some of these have already yielded ore for experimental purposes, and the author considers that they are capable of commercial development. The systematic working of these deposits seems to offer a more certain and a cheaper source of supply than an attempt to develop the occasional occurrences which have been reported from the neighbourhood of the English granites.

[1] 'Report on the Molybdenum Ores of Canada,' Ottawa, 1911.

The occurrence of molybdenite has been recorded for the following localities[1] in Great Britain:—

Cornwall.—Wheal Mary, Lelant; Wheal Friendship, Marazion; Drakewalls Mine, near Calstock; Gwennap Parish; Wheal Gorland and Wheal Unity, St. Day; Gwinear; Menabilly, near Fowey.

Cumberland.—Keswick; Carrock Fells; Brandy Gill, near the source of the Caldew, 4 miles S.W. of Hesket Newmarket; Caldbeck Fell.

Westmorland.—In the Shap Granite.

Leicestershire.—Mount Sorrel.

Sutherland.—Shinness.

Ross-shire.—Inchbae.

Inverness-shire.—Dochfour burn, and about 1 mile to the east of this locality; Glen Elg.

Argyllshire.—Glen Creran, Corrie Buidhe; Loch Etive, at Barrs Quarry, 7 miles above Bonawe; Ben Cruachan, at the granite-quarries.

Aberdeenshire.—Near Inverurie, at Middleton of Balquhain.

Perthshire.—Loch Tay, at Tomnadashan, near Killin.

Kircudbright.—At Almorness Head.

Wigtownshire.—In the Galloway, Dumfriesshire and Wigtownshire Hills.

The collection of Scottish minerals in the Royal Scottish Museum contains specimens of molybdenite from the following localities: Shinness and Auchen, Naver, Sutherlandshire; Barr's Quarry, Loch Etive, Argyllshire; Tomnadashan and East Tulloch, Ardtalnaig, Perthshire; Almorness and Hestan Island, Kirkcudbrightshire.

A brief description of the Tomnadashan and Ardtalnaig ore deposits (Loch Tay, Perthshire) is given by J. S. Grant Wilson and H. M. Cadell ('The Breadalbane Mines,' *Proc. Roy. Phys. Soc. Edin.*, vol. viii, 1884, p. 204). They state that at Tomnadashan, where copper was the metal sought for, 'thin plates and scales of molybden-glance are found in quartz veinlets traversing the granitic rock.'

Chromite or Chromic Iron-ore.

Chromite, or chromic iron-ore, the principal source of chromium and its salts, is a black, metallic-looking mineral with brown streak, and non-magnetic. It consists, when pure, of iron oxide and chromium oxide (FeO, Cr_2O_3), but it generally contains magnesia and alumina in variable quantities, replacing its essential components. Pure chromite has 68 per cent. of oxide of chromium. The mineral occurs as black grains, often rounded, but sometimes well-formed octahedral crystals with sharp angles and corners. It is practically always associated with ultra-basic

[1] In this list the English localities are those given by Greg and Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 348. The Scottish localities are from Heddle, 'Mineralogy of Scotland,' 1901, vol. i, p. 15.

igneous rocks, of the peridotite—or serpentine—class, through which it is disseminated in scattered grains, forming less than 1 per cent. of the rock mass. Practically all the Scottish serpentines contain small amounts of chromite, or of the closely allied mineral, picotite.

Not unfrequently, however, the chromium-bearing minerals form bands, streaks, or irregular lumps in the igneous rock, and weather out prominently on the exposed surfaces. In the Tertiary peridotites of Skye and Rum chromite has long been known to occur, though not in such quantities as would repay working on a commercial scale. The following analyses show that the mineral is by no means pure, but contains considerable amounts of magnesia and alumina, so that it may be regarded rather as belonging to picotite than to chromite proper:—

	I.		II.
SiO_2	6·236	.....	1·19
TiO_2	—	.....	0·34
Al_2O_2	18·279	.....	46·54
Cr_2O_3	26·343	.....	17·55
Fe_2O_3	—	.....	6·01
FeO	34·112	.....	10·10
NiO, CoO	—	.....	0·24
MnO	0·752	.....	trace.
MgO	14·086	.....	18·35
CaO	6·382	.....	0·43
	106·190	.....	100·75

I. Chromite (impure) in peridotite, north-west front of Askival, Rum. *Anal.* M. F. Heddle. *Trans. Roy. Soc. Edin.*, vol. xxx, 1882, p. 461.

II. Picotite in peridotite, Loch Scavaig, Skye. *Anal.* W. Pollard, 'Tertiary Igneous Rocks of Skye' (*Mem. Geol. Surv.*), 1904, p. 70.

In two localities in Scotland masses of serpentine are known that contain chromite on a sufficient scale to induce an attempt to work them as mineral deposits. The chromite never forms a true vein, but is found to occur as lumps of varying size and irregular shape, which have evidently segregated or separated out from the molten igneous rock during cooling and crystallisation. These masses may be many yards in diameter, but sooner or later they are worked out and search must be made for other similar deposits in the serpentine rock.

Corrycharmaig (abandoned).

Proprietor, Marquis of Breadalbane.

Maps: One-inch Geological Sheet 46; six-inch Perthshire 67 S.E.

Four miles W.N.W. of Killin Station, Loch Tay. A road leads to within half-a-mile of the mine.

The mine is situated on the slopes of a hill called Dun Garbh Beag, which is shown on the one-inch geological map as consisting of epidiorite, a metamorphic form of gabbro and serpentine. The epidiorite outcrop occupies about a third of a square mile, and, as most of it is free from drift, the surface can be carefully searched. Many years ago the chromite was worked under a former Marquis of Breadalbane, and several small pits or quarries were opened for chromite, as well as one small drift; but all the workings have been

closed for a long time. From an account of the mine written in 1884 by Mr. J. S. Grant Wilson,[1] who mapped this district for H.M. Geological Survey, we extract the following particulars:—

"The chrome iron-ore appears to be disseminated through the serpentine in detached grains or aggregates, and no vein is to be seen. It occurs in masses, sometimes angular, but more often reniform or lenticular in shape, and varying in size from that of a pea to great blocks, 5, 10 and, in one instance, as much as 30 tons in weight. Small cavities lined with octahedral crystals of the ore are not uncommon. The minerals associated with it are actinolite, steatite, chrysolite, and magnetic and copper pyrites. From the trial workings made over this field about 60 tons of ore were raised and sold in 1855-56, but the ground is still practically unproved. The following analysis was made by W. Valentine in 1862:—

Sesquioxide of chromium	36·86 per cent.
Protoxide of iron	20·27 per cent.

The ore fused with the greatest facility, and 100 lbs. would be capable of furnishing about 70 lb. of bichromate of potash.

Analyses of three specimens, made in the laboratory of the Cleveland Steel Works in 1884, give:—

	Per cent.	Per cent.	Per cent.
Sesquioxide of chromium ...	37·18	38·79	25·50
Protoxide of iron	19·30	23·14	25·71
Protoxide of manganese	0·18	0·27	0·19
Silica	10·94	11·20	17·00
Sulphur	0·06	0·05	0·07
Phosphoric acid	0·06	0·05	0·06
Lime	Trace.	Trace.	Trace."

Balta Sound.

On the north side of Balta Sound, in Unst, Shetland, chromite was worked at one time on a fairly extensive scale, and about 100 tons were obtained in 1914, but the mine is now closed.

The chromite occurs in serpentine not as true veins, but as masses or segregations, some of which weigh many tons. The serpentine mass of Unst is a large one, extending from Norwick in the north-east corner of the island to the Head of Mula on the south coast, a distance of more than 10 miles, and it forms most of the district around Balta Sound, Haroldswick and Hagdale. What is probably an extension of the Unst Serpentine occurs in Fetlar, the next island to the south of Unst. Chromite is found in scattered grains probably in the whole of this great serpentine outcrop, but attempts to work it on a commercial scale have been made only near Balta Sound and Hagdale. The district has not been mapped by the Geological Survey, but a Mineralogical Map of Shetland was prepared by Professor M. F. Heddle and issued by the Mineralogical Society in 1879 (*Mineralogical Magazine*, vol. ii, No. 12), and in 1883 a geological map of Shetland appeared in Tudor's 'The Orkneys and Shetland' (London: Stanford), compiled by Dr. B. N. Peach and Dr. John Horne.

The discovery of chromite in Unst seems to have been made by

[1] *Proc. Roy. Phys. Soc. Edin.*, vol. viii, 1884, p. 201.

Dr. Samuel Hibbert about the year 1817 (Hibbert's 'Shetland Isles,' Edin., 1822, p. 363). His account of the discovery is as follows:—

"I was indeed first led, in the year 1817, to a search after this mineral by observing innumerable fragments of it strewed about the hill, which must have been loosened by the disintegration of the rock in which they were contained. They were chiefly found in a direction due west from Hagdale as far as the Hill of Crucifield. One of these weighed 1 cwt. 20 lbs.; but I saw a mass which must have been considerably larger, since it was immoveable from its site without a great effort. West of Hagdale several embedded masses of the chromate of iron may be observed, of a size corresponding to the loose fragments that are found of the ore. In several places the chromate of iron occurs in the form of numerous thin, ramifying veins, from two to three inches in breadth, but occasionally increasing to the breadth of five or six inches. Within, perhaps, a hundred yards of the house of Buness a very considerable mass is found, the extent of which is not apparent, since it is on one side concealed by the sea and on the other by the deep soil of a meadow. It can be traced three feet in breadth and fifteen feet in length; but its magnitude must be much greater than this."

Shortly afterwards the exploitation of the chromite deposits began and was carried on principally by Mr. Edmondston, of Buness. No statistics of the output are available, but from the size of the excavations left it is safe to conclude that several thousand tons were obtained. The quarries are situated on rising ground above the fine natural harbour of Balta Sound, and we are informed that the ore was carried in ships to Leith or Bo'ness in the Firth of Forth. This seems to have gone on for about 15 years, but was discontinued about the year 1845. In the 'New Statistical Account of Scotland' (Edin. 1845, vol. xv, Shetland, p. 45) it is stated that "Chromate of iron has been raised and carried to market in its crude state in considerable quantity, for which a very fair price was at first realised; but of late it has been discovered in Norway and in other places, and the free importation of it being allowed, the price now offered is very low."

Professor Heddle was well acquainted with this part of Shetland, and a few interesting particulars regarding the chromite deposits may be gleaned from his account of the mineralogy of Unst. In 1878 he stated that "On the shoulder between the hill of Heyoags and Keen Hill, a great quarry of *chromite* was formerly wrought. After sinking to a depth of about 86 feet the ore ceased; many thousand tons were here obtained.

It unquestionably, judging even from the appearances to be seen at this spot, formed part of a vein. The vein runs somewhat to the north of due east and west from the point where it is first seen, thus being nearly synchronous with the strike of the rock as seen in the hill ranges. The vein does not everywhere carry ore—that occurs only occasionally as 'bunches.' The vein has been wrought, here and there, along a stretch of perhaps a mile and a half; it throws one or two off-sets, in the neighbourhood of the house of Buness." (*Mineralogical Magazine*, vol. ii, 1878, p. 22.)

Heddle gives two analyses of the Unst chromite: —

	I.		II.
FeO	17·52	.....	18·08
MnO	·5	.....	Trace.
Cr_2O_3	44·56	.....	48·03
Al_2O_3	23·74	.....	16·55
CaO	1·29	.....	0·88
MgO	—	.....	16·61
SiO_3	11·09	.....	0·83
	98·70	.....	100·98

I. Chromite; Hagdale, Unst, Shetland; *anal.* Heddle.
II. Chromite; Buness, Unst, Shetland; *anal.* Heddle.

These show that it contains alumina and magnesia in considerable amounts, and Professor Heddle remarks that "The immense amount of working which has recently been carried out on Sobul Hill, Unst—the size of the water-filled quarries, and the quantity of stacked and unsaleable ore prove that if chromite does not pass by insensible gradation into *Picotite*, the average exploiter is at least quite unable to discriminate between the two minerals." (Heddle, 'Mineralogy of Scotland,' 1901, vol. i, p. 101.) In other words, a good deal of the chromite raised in the workings proved to be of poor quality, as much of the chromic oxide was represented by alumina.

The Ordnance Survey maps on the scale of six inches to one mile (Sheets 2 and 5, Orkney and Shetland) show the positions of ten or twelve chromite quarries scattered over the moor between Haroldswick and Balta Sound. The largest quarries are those above Buness House and near the Wick of Hagdale, the latter being 50 yards in diameter, and, according to Heddle, 86 feet deep. Most of the quarries are much smaller than this, some being obviously mere trial pits sunk to test a show of ore appearing at the surface. There is no regularity in the distribution of the pits, such as might be expected if the chromite occurred in well-defined veins having a regular strike. It seems certain that the ore was found in lumps or irregular ore-bodies, and that each quarry was discontinued when the ore was worked out. Many of the pits are now full of water. No shafts or mines were sunk, and there are no drifts, such as might have been opened on the course of a vein. Around the quarries there are large spoil heaps, consisting of lumps of serpentine more or less rich in chromite, and samples of the ore can readily be obtained, though no doubt the best of it was removed. Much of what is left contains a yellowish-green serpentine, which forms a sort of matrix in which the black chromite grains lie embedded. This was the state of the mines in 1907, but in 1914 100 tons of chromic iron-ore are said to have been extracted. Subsequently, however, working was discontinued, and at present the mines are closed.

Chromite occurs also in the serpentine of Fetlar, the island lying to the south of Unst. It is mentioned by Heddle, and Charlton states definitely that there is an old chromate mine there.[1]

[1] 'A visit to Shetland in 1832,' *Old Lore Miscellany of Orkney, Shetland, etc.*, vol. vii, 1917, p. 29.

Talc and Steatite (Soapstone, Soap-rock and Potstone).

Talc and steatite (soapstone and potstone) are essentially the same mineral in different states of aggregation. The purer varieties, which show a fibrous or leafy structure, are more commonly called talc, while impure, massive, fine-grained varieties are described as soapstone and steatite. The essential mineral is a hydrated silicate of magnesia, but impurities such as tremolite, pyroxene, calcite or dolomite, chlorite, quartz, and iron oxides are commonly present, rendering the mineral of inferior quality. Many varieties of pale-coloured mica are known in trade as 'talc,' though they have no valid claim to that designation. All forms of talc are very soft, have a distinctly soapy feel, and are rather resistant to acids.

Talc finds many uses, the principal being as an ingredient of smooth-surfaced papers, in the manufacture of rubber goods, for filling cotton and other fabrics, and as a dusting powder in medicine. Tailors' chalk consists of talc or steatite. Laundry basins, vats, etc., are sometimes made of steatite. Paints and plasters may contain powdered talc, and, on account of its insulating properties, steatite is useful in the electrical industries.

Cornwall.

The occurrence of soap-rock in Cornwall was noticed by Borlase in 1758[1], and Pryce, in 1778, mentions soap-rock and steatite.[2]

Veins of steatite and talc are not uncommon in the serpentine near Kennack, Mullion, the Black Head, Pentreath, and to the west of Kynance. They are always small and usually discontinuous. At two places they have been worked commercially. Majendie, in 1818, stated that steatite had been raised near Mullion Church Town. The locality appears possibly to have lain in Predannack, $1\frac{1}{2}$ miles south of Mullion, where there is an old steatite mine called Wheal Foss. At the second locality, Gew Graze, the soap-rock (or pseudophite) was worked at several periods about the beginning of last century as a source of steatite. The soap-rock is a steatised vein of granite, about 3 or 4 feet thick, and nearly vertical. It was worked in an open cutting, and about 12 tons were annually raised. In 1819 working had ceased. An analysis shows 37·94 per cent. of silica, 14·25 per cent. of alumina, 31·08 per cent. of magnesia, and 14·83 of water, with small quantities of oxides of iron, manganese and sodium.[3]

Of late years, soapstone has appeared occasionally in the Home Office Reports. In 1894, 10 tons were raised; in 1897, 28 tons; in 1912, 8 tons; in 1913, 40 tons; in 1914, 180 tons.

Scotland.

Rocks consisting in large part of talc, though not common, have a wide distribution in Scotland. Practically all of them belong to the Highland metamorphic group. Some are undoubtedly weathered or altered forms of peridotite, *i.e.*, igneous masses rich in olivine and pyroxene which have been considerably decomposed

[1] 'Natural History of Cornwall,' by Borlase, 1758.

[2] 'Mineralogia Cornubiensis,' by Pryce, 1778.

[3] Condensed from an account given in 'The Geology of the Lizard and Meneage' (*Mem. Geol. Survey*), 1912, p. 262 and (analysis), p. 144.

and transformed. Others are 'schists' with a platy or foliated structure, which may have been at one time igneous rocks; but talc-schists also are frequently associated with limestones in such a way as to suggest that the talc has developed from magnesian silicates which were in the first place produced from the impure limestone by metamorphism.

The most important occurrence of steatite or potstone in Scotland is that of Fethaland, at the northern extremity of the mainland of Shetland. Probably this potstone was known and worked in prehistoric times, and the locality at which it occurs is called Klebber Geo, which in the original Norse signifies Potstone Bay. Heddle has given a geological description of Fethaland (*Mineralogical Magazine* vol. ii, 1879, p. 162), from which it appears that the peninsula consists of gabbro with chlorite-schist, potstone and actinolite-schist. The steatite is soft, massive, yellowish or greenish, and forms a bed intercalated with the schists. Heddle describes as 'potstone' from this locality a dark brownish-green rock with spangles of light-coloured talc. It is said to be in places so soft that the natives formerly used it as an ointment. There are small quarries at this locality where the stone has been worked, but never on a large scale. We understand that within recent years a small amount of steatite has been quarried here, but from the exposed nature of the situation and the distance from a market the work is now discontinued.

Talc occurs in veins of pale-green, scaly crystals in Unst (Shetland), and in Balta Island there is said to be very good steatite. In the island of Fetlar talc-schists occur in several places, and a vein of talc was being worked there in 1914, but mining was discontinued owing principally to difficulties of transport arising from the War. The mineral was sent by boat to Lerwick and was ground in mills at Bonnybridge, near Falkirk. It is said that two veins were worked, one 4 ft. and the other 7 ft. in width. Both Heddle and Charlton (*loc. cit. sup.*) record localities for talc, steatite and talc-schist in Fetlar. Another locality from which steatite has been obtained is Eilean Glas, in Harris, one of the Outer Hebrides.

The talc-schists of the Highlands of Scotland have never proved to be of a quality which would render them of value for industrial purposes. Most of them have too many impurities which form hard, brittle particles when the rock is pulverised; or they cannot be got in slabs large enough to be used in constructing apparatus. Locally, the purest varieties have been employed as a lubricant or as a dusting powder. Dark-green, massive, chloritic potstone has been used as a building-stone at Inveraray Castle. A vein of good steatite is said to occur on the shore of Loch Alsh, near Ardintoul (Sheet 71), but it has not been mined. The pre-Torridonian ultra-basic dykes that intersect the Lewisian Gneiss of Western Ross and Sutherland are often rendered talcose by shearing.

Diatomite.

Diatomite is a fine-grained, earthy substance, somewhat resembling chalk or white clay in appearance, and, when dry, easily broken down to a fine powder. The purest specimens are white in colour, but the less pure varieties, especially when moist,

are grey, yellowish or brownish, according to the amount and nature of impurity present. The colour is due to admixture with clay, peat or iron oxide; and often diatomite, which is pale-brown in its original state, when dug up, becomes nearly white on drying. A lump of diatomite, in addition to its softness, is characterised by its low specific gravity and the great readiness with which it absorbs water and other liquids. Some specimens are almost as light as cork. Good diatomite will absorb four times its weight of water. The particles of which it consists are hard and will scratch polished brass or glass, and resist the action both of fire and of acids.

These properties arise from the composition of diatomite. It consists of extremely minute siliceous organisms known as *Diatomaceæ*, plants of lowly organisation, which may live in fresh or salt water. The organic material of the plants has usually disappeared leaving the siliceous cells empty, and thus giving the material its porous character. The silica of the 'frustules,' as they are called, is in the colloid or opaline state, together with a little water. It is not attacked by boiling acids (except hydrofluoric) or by being exposed to a red heat, but is slowly dissolved by alkalies.

Most diatomaceous deposits have been laid down in fresh-water lakes or swamps, usually in districts formed of resistant rocks where rainwash is absent, and often in association with peat. In many lakes diatoms abound, and, under suitable conditions, diatomite is still accumulating.

Diatomite is used as an absorbent for nitro-glycerine and other explosives. It serves well for polishing metals. As a non-conductor of heat and sound it is useful for packing boilers, steam-pipes and refrigerating apparatus, and floors of buildings. Mingled with a little clay and sawdust it makes a light, porous, fireproof brick used for floors and partitions. It serves as a filler for rubber and cotton fabrics; as an ingredient of paints, and as one of the raw materials for making ultramarine and silicate of soda; as a filter-powder and as a tooth-powder.

In Scotland diatomite has long been known to occur and has been worked in Skye and Aberdeenshire in an intermittent way for over thirty years. The British production in 1913 was 154 tons, worth £308. The most important source is in the north of Skye. At Loch Cuithir, or Quire, the deposit is said to be 40 feet thick and was worked at one time by the British Diatomite Company, and more recently by the Skye Mineral Syndicate Company. A tramway three or four miles long connects the pits with the shore at Inver Tote. The material is pure, and in the air-dry state contains 94·40 per cent. of silica and 4·43 per cent. of water; after being heated to expel the water it contains 98·78 per cent. of silica. It has a high absorbent power. According to Mr. J. S. Grant Wilson and Mr. Ivison Macadam diatomite occurs also in Loch Mealt, Sartil, Loch Cleat, Loch Snuisdale and Glen Uig.[1] Some of these have been worked on a small scale. Loch Monkstadt has been drained and a deposit of diatomite has been proved, which varies in thickness from 1 ft. 6 in. to 3 ft. Analyses and tests of absorbent power are given in the paper referred to.

[1] *Trans. Edin. Geol. Soc.*, vol. v, 1886, p. 318.

In Aberdeenshire, near Ballater, diatomite was discovered about the year 1880 as a layer underlying peat in Dinnet Moss and near Loch Kinord. First described as 'white peat,' it was recognised as a diatomaceous deposit by the Rev. George Davidson. He reports that the organic matter, mainly peat, is about 39·25 per cent., the remainder being principally diatom-frustules with some sand and clay. An analysis by Mr. Ivison Macadam shows that the inorganic portion contained 82·96 per cent. of silica with 5·50 per cent. of iron oxide, 2·10 per cent. alumina and 2·93 per cent. magnesia. It is not remarkable for its purity but compares closely with specimens of German 'kieselguhr.'[1] Mr. Davidson states that the Black Moss, 1½ miles north-east of Loch Kinord, was carefully examined by sinking shafts, and was found to contain rather more than 800,000 cubic yards of kieselguhr, 6 cubic yards of which, when thoroughly dried, would make a ton. This deposit has been worked for years, but intermittently as the workings are flooded with water after wet weather. The surface peat, from 2 to 4 ft. thick, is used for fuel, or torn up to make moss-litter. Under the peat lies a layer of diatomite of unknown thickness. It contains a sufficient quantity of peaty matter to be coherent when dried, and it is dug out and dried on wooden frames exactly in the same manner as peat. When air-dry it is pale-brown or grey in colour. Practically the whole output is sent to explosive works at Ardeer, Ayrshire, where the organic matter is burnt away in a kiln before the material is used. An analysis of the peaty diatomite made in the laboratory of H.M. Geological Survey shows:—Loss on ignition (moisture, combined water, organic matter, etc.), 50·85 per cent. The residue is white and contains 91·5 per cent. of silica, 1·5 per cent. alumina, 1·5 per cent. iron-oxide, 2·0 per cent. lime with smaller amounts of magnesia and alkalies. The diatomite-workings are situated on the property of Mr. J. C. Barclay Harvey, of Kinord, Dinnet, Aberdeenshire.

Less important deposits have been reported from a few other localities in Scotland. One occurs in Lewis, at Gress, near Stornoway.[2]

The diatomite of North Tolsta, in Lewis, has been described by Mr. Rattray in the Transactions of the Royal Society of Edinburgh (vol. xxxiii, 1887, p. 419). It is stated to be 1½ acres in extent and 7½ feet in thickness.

Another deposit has long been known from the island of Mull, near the lower end of Loch Ba. It was supposed to have been destroyed by agricultural operations, but was re-discovered by Mr. Tait in 1915. The diatomite is from one to two feet thick, and is not pure.[3]

In 1915 an extensive diatomite deposit was found by Mr. James Duncan, of the Royal Scottish Museum, at the east end of Loch Leven, in Fife, but it occurs in cultivated land, is often impure, and its thickness is not more than one or two feet. A description of this deposit has been read to the Geological Society of Edinburgh.

[1] *Trans. Edin. Geol. Soc.*, vol. iv, 1883, pp. 211 and 277.

[2] *Journ. Roy. Micro. Soc.*, vol. ii, 1882, p. 665.

[3] W. Gregory, *Quart. Journ. Micro. Sci.*, vol. i, 1853, p. 92, and vol. ii, 1854, p. 24.

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